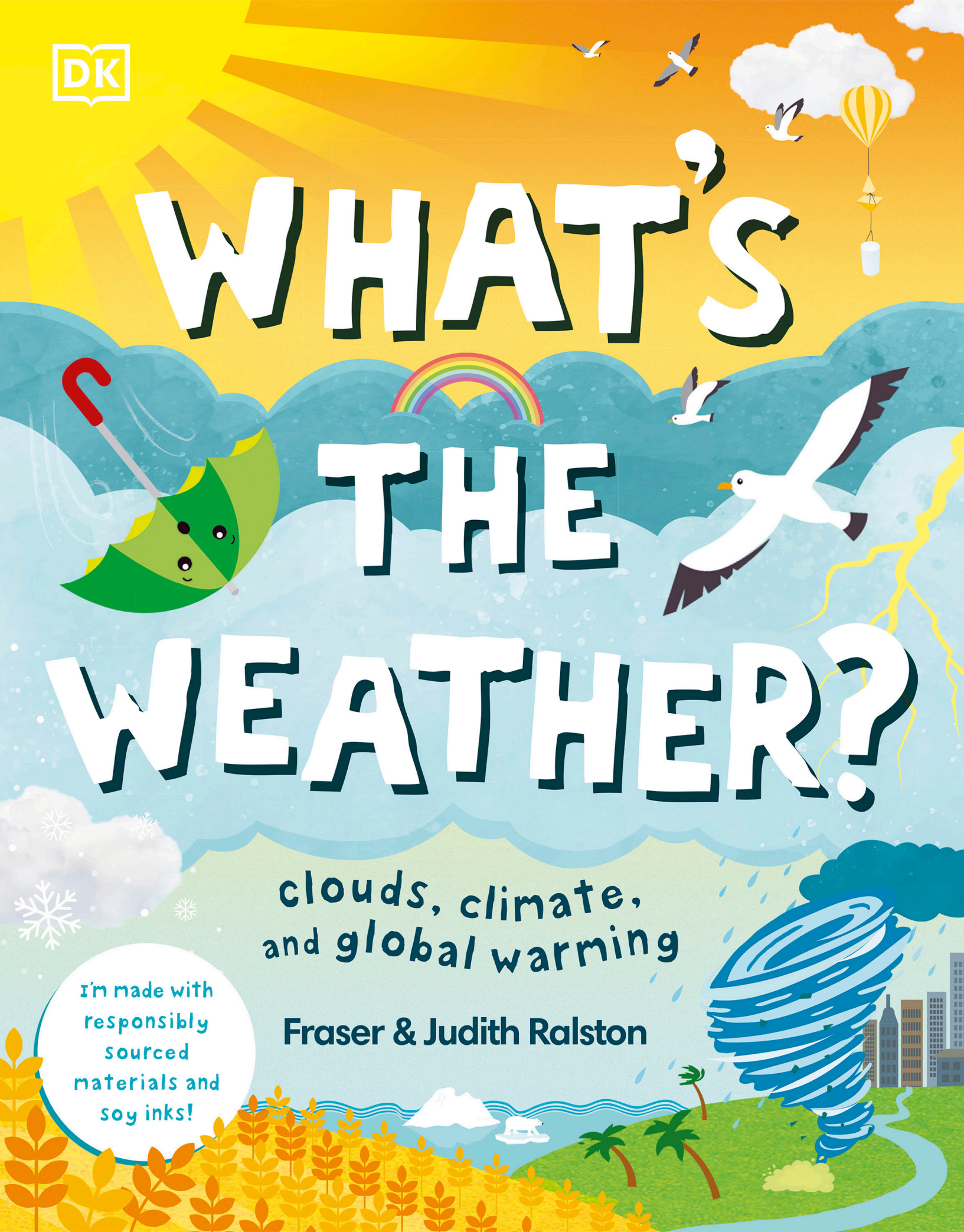
DK
WHAT'S THE WEATHER?
clouds, climate, and global warming
I'm made with responsibly sourced materials and soy inks!
Fraser & Judith Ralston

DK

WHAT'S THE WEATHER?

Fraser & Judith Ralston

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For the curious
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Introduction

Weather was a major part of my childhood. I lived on the shore of Portobello Beach outside Edinburgh, Scotland. The east-coast haar, a misty, low cloud, would often envelope the garden. Sometimes an easterly gale caused the waves to lash right up to the front door! I began to recognise the signs for different weather, learning what the sky was telling me. There was always something interesting going on.

I grew up to become a weather presenter at BBC Scotland. When I tell people about the weather on television, I imagine what it looks like over different parts of the country. I enjoy breaking down the science so people watching at home know if it will be stormy, snowy, or sunny. It is an incredible job.

Being able to write this book has been an absolute joy. I hope you enjoy it, and remember to keep looking up at the sky – weather never stays the same!

Judith Ralston

Judith Ralston

Weather presenter

During my childhood in Glasgow, Scotland, we experienced some historic weather events. There were back-to-back scorching, dry summers in 1975 and 1976, during which I became addicted to ice-creams, ice lollies, and sea dips on the Clyde coast. Several severe winters swiftly followed, from the late 1970s to the early 1980s. We made the most of snowfalls that came with the toe-numbing low temperatures by sledging and ice-skating.

These events sparked my interest in weather, which grew as I saw great windstorms, fogs, and even funnel clouds from my living-room window. I got a job in meteorology, the science of weather, a year after leaving school. From there, I have worked in lots of weather-related jobs, including three working trips to forecast in the coldest continent on the planet – Antarctica.

Knowing a little about what causes weather makes it all the more fascinating, which is what this book aims to help you do.

Fraser Ralston
Chartered meteorologist

Hot or cold?

The relationship between the Sun and the Earth is the main cause of hot or cold weather. However, currents of air in the atmosphere and of water in the ocean affect the temperature, too.

Atmosphere

The atmosphere is a thin layer of air surrounding the Earth. It acts like a protective skin by blocking out harmful particles from the Sun. All our weather develops within the atmosphere.

Warm and rainy

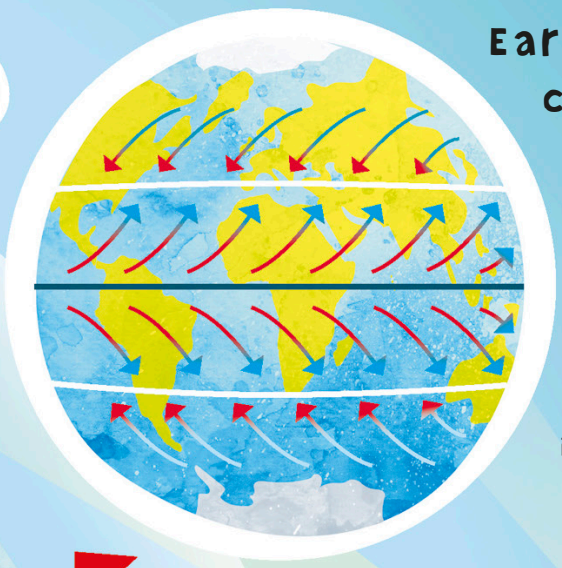
Cold and dry

Climate

Weather conditions over a long period of time form a climate. There are different climates around the world.

Earth air conditioning

Air currents swirl around in the atmosphere. These act like an enormous temperature engine. They transport warm air away from the tropics and cold air away from polar regions. This effect is called general circulation.



Ocean currents

Massive movements of water around the globe, called currents, transfer warm and cool ocean water. This affects local weather.

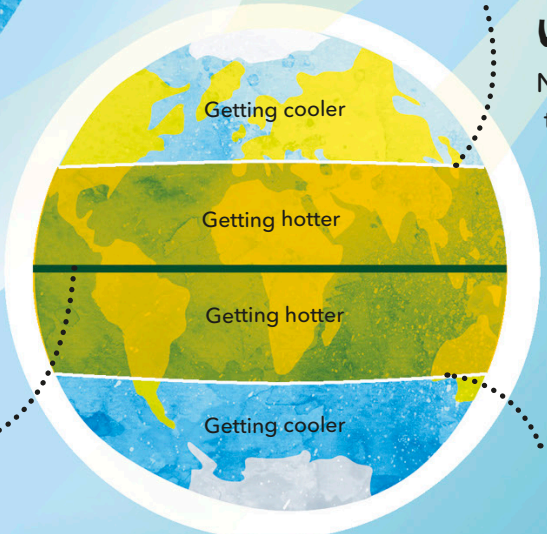
The **tropics** are the areas either side of the Equator.

South Pole

The Sun

The Sun's rays hit the Equator straight on, making it hot. Other parts of the Earth are hit at an angle, so the heat is spread out across a greater area. This makes them less warm.

The area 40 degrees north of the Equator is called 40N.



Equator

The area 40 degrees south of the Equator is called 40S.

Up and down

North of 40N and south of 40S the Earth loses heat. South of 40N and north of 40S the Earth gains heat. The general circulation then acts like a global air-conditioning machine by cooling some areas and heating others.

Through the year

It is spring in areas that start to tilt towards the Sun...

...summer in areas that tilt towards the Sun...

Spring

During spring, days get longer and nights get shorter. Temperatures steadily rise. The warmer weather means that some flowers start to grow and many trees begin to grow leaves.

Summer

This is the warmest time of year, with long hours of daylight. It happens from June to August in the northern hemisphere (above the Equator), and December to February in the southern hemisphere (below the Equator).

Many areas have less cloud during the summer months.

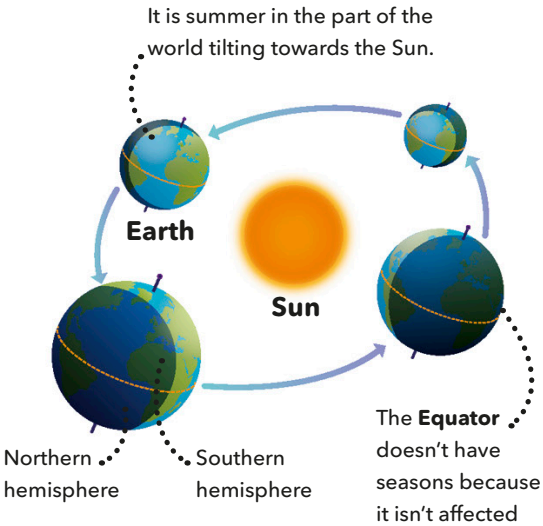
Deciduous trees that were bare in winter start to grow leaves and blossom again.

Lots of flowers grow in the warm summer weather, and plenty of butterflies can be seen.

Some animals, such as hedgehogs in Europe, emerge from hibernation, which is like a deep sleep.

Seasons

The Earth is tilted. As it circles the Sun, different parts lean towards or away from it. This means they get more or less heat, causing seasons.



In most parts of the world, the weather changes throughout the year. The temperature rises in some months and falls in others, and there is a variety of weather. These periods of different weather are called **seasons**.

...autumn in areas that start to tilt away from the Sun...

...and winter in areas that tilt away from the Sun.

Autumn

The days get shorter and the weather starts to turn cooler in autumn. It can become very wet and windy. However, some mornings glitter with frost.

The leaves of deciduous trees turn golden colours and begin to fall.

Deer mate in autumn, so that babies are born when it's warm again in spring.

American black bears eat lots to prepare for hibernation.

Winter

The days become very short in winter. The weather turns colder. There is more rain, with snow and freezing fog in some places. Some animals go into a sleep-like state, called hibernation.

The Sun is low in the sky and not much of its heat reaches the ground.

Some animals, such as the snowshoe hare in the USA, have white coats to blend in with snow.

Light nights

The North and South Poles are tilted in such a way that they get constant sunlight at one point of the year, and no sunlight at all at another.

A "midnight Sun" shines all day and night during midsummer.

During midwinter, the Sun never rises!

Early weather

The Earth didn't always have weather like it does today. Our planet was much hotter when it was newly formed. There was no water, clouds, or wet weather. In fact, there was once almost no atmosphere in which clouds could have formed!

Explosive impacts

When our planet was first formed, gigantic rocky debris, called planetesimals, were constantly colliding with its surface. These explosive collisions caused the hottest temperatures in history.

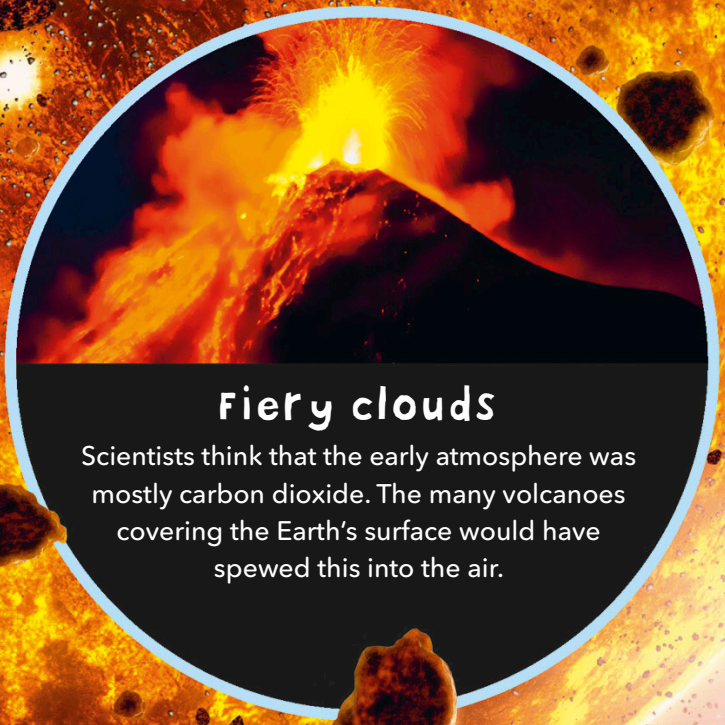
Top-of-the-atmosphere temperatures were above 1,982°C (3,600°F)

Extreme heat

Scientists study rocks to find out what temperatures were like in the past. Even after collisions stopped heating the Earth, it seems surface temperatures reached more than 204°C (399°F) – around four times hotter than today's hottest temperatures.

Melting rock

At very high temperatures, rock becomes thick liquid, or molten. The early Earth was so hot that its rocky surface was kept molten.



Fiery clouds

Scientists think that the early atmosphere was mostly carbon dioxide. The many volcanoes covering the Earth's surface would have spewed this into the air.

There are no records of rainfall during this volatile period.

The first rain

Water was probably brought to the Earth on icy meteorites. The planet cooled down over millions of years. Water vapour (the gas version of water) began to cool in the air, forming droplets in clouds and rain.

Telling the weather

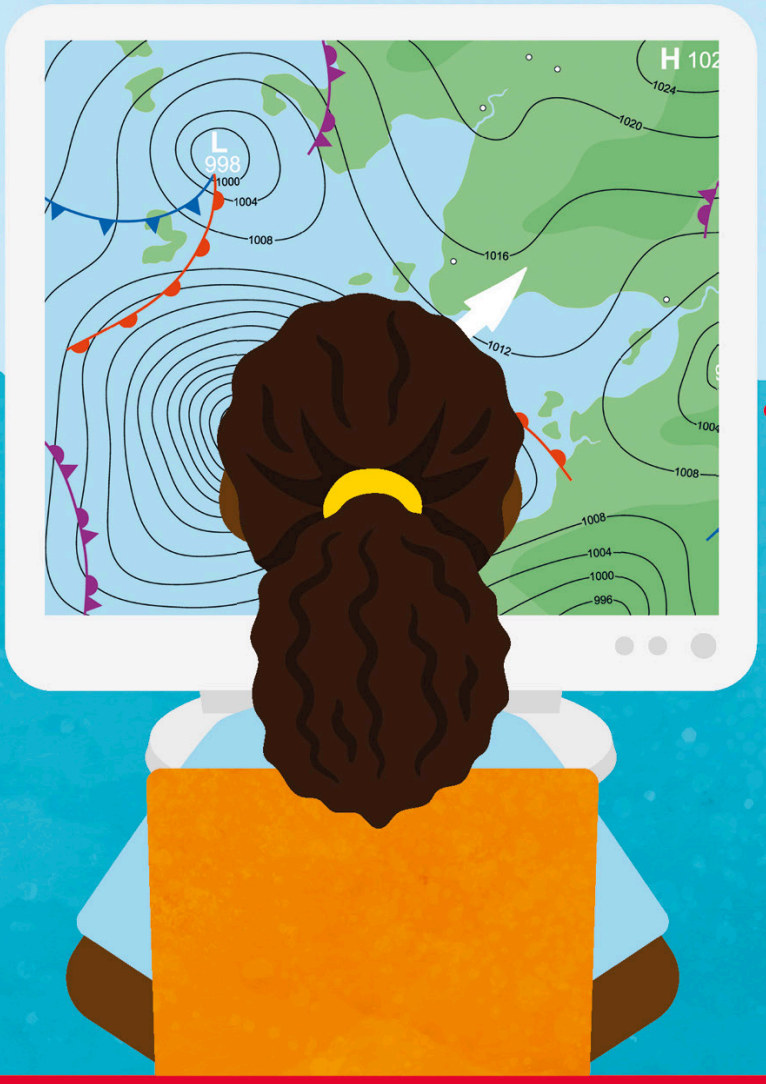
Weather forecasts use a very large variety of information to predict the weather. Forecasters receive information 24 hours a day, 365 days a year. They carefully examine and compare the facts, and then decide what kind of weather is most likely.

Weather balloons

Instruments to take measurements high in the air are sent up beneath special balloons. These are released at the same time twice daily, from 800 stations worldwide.

Weather stations

At important stations, instruments and human observers measure weather. This includes wind speed, humidity, cloud types, and rainfall.



Black lines show air pressure and coloured lines with symbols show weather fronts.

Forecasting

Computers are used to collect weather data from all the monitoring sources. They create models that show what the weather could look like. These can be local, show an entire continent, or even display the whole planet.

Every few hours forecasters use new data and their experience

Satellite imagery

We can see the weather from space using satellites that circle the Earth or stay above one spot. They send back digital pictures of cyclones, dust storms, and more.

Aircraft and shipping reports

Planes and ships carry instruments to measure the weather, to help make sure their journeys are safe. Their findings are also useful for forecasters!

Forecasts for ships use code words that carry lots of information about the weather.

Radar

Rain and snowfall are picked up by radar systems dotted across the land. You can learn more about radar on page 45.

to update maps and models.

Types of predictions

The weather affects people in different ways. Forecasters create different reports to suit these needs.

Pilots need detailed reports to know it's safe to fly!

Gritters need to know if ice will form. They spread salt that mixes with water to stop it freezing.

Farmers need to know if there will be rain or sun, and the humidity, as these affect crop growth.

Normal people, like you, want to know the general weather so they can plan what to do with their day!

Governments need to know about extreme weather, so they can help people stay safe.

Around the world

The weather varies as you travel away from the warm Equator towards the freezing poles. There are distinct zones featuring similar climates and weather. Here are some of the largest zones.

TROPICAL
Near the Equator, it is hot and wet almost all year round. There is rainfall most days. A little further from the Equator, there are short, drier seasons.

DRY
This zone includes deserts with very little rain, and regions that have only a short, unreliable rainy season. Deserts tend to be hot in the daytime and cold at night.

MEDITERRANEAN
Summers are hot, with long, dry periods and occasional rain showers. Winters are generally mild and wet, with very brief colder spells.

WARM TEMPERATE
This zone has four seasons. Rain falls in all of them – especially in summer, when it is very warm. Winters are mostly mild, but with some colder spells.

COOL TEMPERATE
There are four seasons, with rain all year round. Regions near oceans catch lots of rain, with few temperature extremes. Landlocked areas get less rain, with bigger temperature changes.

MOUNTAIN
On the tops of mountains, heavy rain or snow often falls. Here, it is much colder than neighbouring low areas and the wind is stronger.

TUNDRA
There are long, very cold winters with frost, snowfall, and short days. Summers are short, but can be quite warm due to long hours of daylight in midsummer.

POLAR
Snow and ice cover the ground almost all year round. Temperatures are usually near or below freezing, and far colder in winter. The weather is often dry and windy.

As you go up a mountain, it gets colder by about 6.5°C (11.7°F) every 1,000 m (3,281 ft).

Clouds

Below 2,500 m (8,202 ft)

Cycle-helmet top

Cumulus

If these bright, white, fluffy clouds grow cauliflower-shaped tops then showers are likely.

Clouds cover about 67% of the Earth.

Stratocumulus

These clouds are quite like cumulus clouds, but much flatter. They are often seen in the sky.

Cumulonimbus

A tall cloud with a cycling helmet-shaped top is a cumulonimbus cloud. It might suggest downpours, hailstones, and thunder.

Stratus

This thin cloud lies very low. It can be like a sheet across the sky, touching the tops of tall buildings, or dark ragged patches seen during rain.

Mammatus

These distinctive clouds look like pouches or bubbles hanging under a dark cloud. They often occur as a thunderstorm ends.

Nimbostratus

A thick, medium-grey, sheet cloud covering the whole sky is nimbostratus cloud. Heavy rain or snow often falls from these clouds.

Crepuscular rays

These can form when sunlight shines through gaps in a cloud. Light hits particles in the air and is split into different colours. Some of these colours appear as rays.

A cloud is a collection of tiny water droplets and ice crystals. Touching one would be like putting your hand in fog. The names for flat clouds contain **"strat"**. Middle-height clouds begin with **"alto"**, and high-up clouds start with **"cirr"**.

2,500–6,000 m (8,202–19,685 ft)

Altostratus

This flat, light-grey cloud blankets the sky. It often signals that rain or snow is on the way.

A cloud forms from the gas version of water, called water vapour. The vapour turns into water droplets and ice crystals when it rises and cools.

Altocumulus

This type of cloud comes in many types. Lenticular altocumulus clouds are shaped like almonds, plates, or even flying saucers!

Cap cloud

This cloud hovers over or just above a mountain top, like the head of a mushroom.

Some clouds have been mistaken for UFOs!

Above 6,000 m (19,685 ft)

Cirrostratus

A very thin sheet of white, icy cloud is called cirrostratus cloud. Through this cloud, a halo can be seen around the Sun. It turns the sunshine hazy and might mean rain is on the way!

Cirrus

These white, delicate clouds look a bit like a cat's whiskers. You can see them when it's dry and sunny.

Cirrocumulus

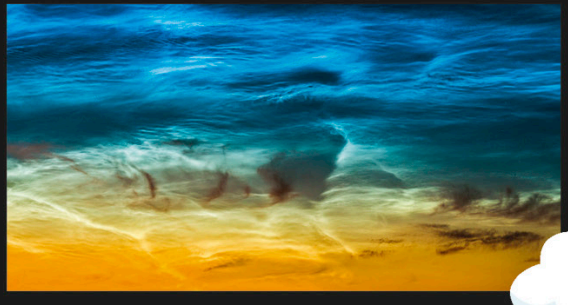
Tufts of high, white cloud are called cirrocumulus. Some cirrocumulus clouds look like ripples in the sky.

Contrails

These are artificial clouds. They are white lines formed by frozen water droplets from aircraft exhausts. They tend to disappear quickly.

Noctilucent clouds

These icy clouds seem to shine like jewels in the night, creating vivid colours. They sit very high up in the sky.



The water cycle

A massive water recycling process is constantly taking place across the globe. Called the water cycle, it takes water into the air and releases it, often far away, as rain. It provides us with drinking water and allows plants to grow. Here's how it works.

Condensation

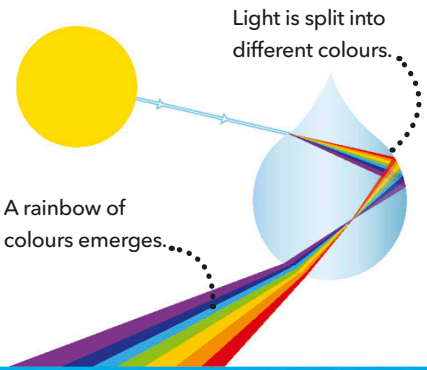
Water vapour cools as it rises through the air, and changes into liquid water droplets to form clouds. The more water vapour that rises, the bigger the cloud that will be created.

Air rises higher over mountains and produces heavier rainfall. On the other side of mountain ranges it is drier, as the air flows down and disperses the cloud.

Rainwater stored in the Earth or in dams can be piped underground across a long distance to dry areas.

Rainbows

Light contains lots of different colours. It can be split into these colours if it passes through the surface of an airborne water droplet and bounces off the opposite side. We see this happens as a rainbow!



Evaporation

As water in the oceans or on land heats up, it changes from a liquid to a gas, called water vapour. Strong winds over oceans help speed up this process.

Precipitation

Gradually, water droplets in clouds bump into each other and grow bigger. They start to fall through the cloud, hitting and joining up with more droplets. They eventually grow heavy enough to fall from the cloud as raindrops.

Each raindrop is made up of about 1 million tiny cloud droplets.

Run-off

Rain that's soaked into the ground and melted mountain snow makes its way into streams. These join rivers.

Back to the Sea

Much of the world's rain falls directly back into the oceans. The rest is transported by thousands of rivers flowing back into the oceans. From here, the cycle begins again.

Types of rain

Different clouds produce a variety of rainfall, including thin drizzles and heavy showers.

Drizzle

Tiny raindrops falling from thin clouds make up drizzle. It is common over coastal areas, and mountains exposed to humid winds.

Showers

Thick clouds produce showers. These are short bursts of rain that are often heavy. Most last for under an hour, or just for a few minutes.

Heavy showers

Large raindrops make up heavy showers, which fall from very thick, dark-grey clouds. They can cause flash floods, which happen quickly and allow little time to react.

Thunderstorms

A single cumulonimbus cloud can develop into the intense weather wonder of a thunderstorm. This can happen almost anywhere in world, if the right conditions are present. A thunderstorm can include lots of different weather, from heavy rain to snow.

A storm brewing

In order to grow, storms need a combination of warmer air near the Earth's surface and much colder air higher up. They also need a lot of humidity. Thunderstorms mostly happen in warm weather, but they can develop in winter, when cold air moves over warmer oceans.

Lightning can heat air to 30,000°C (50,000°F)!

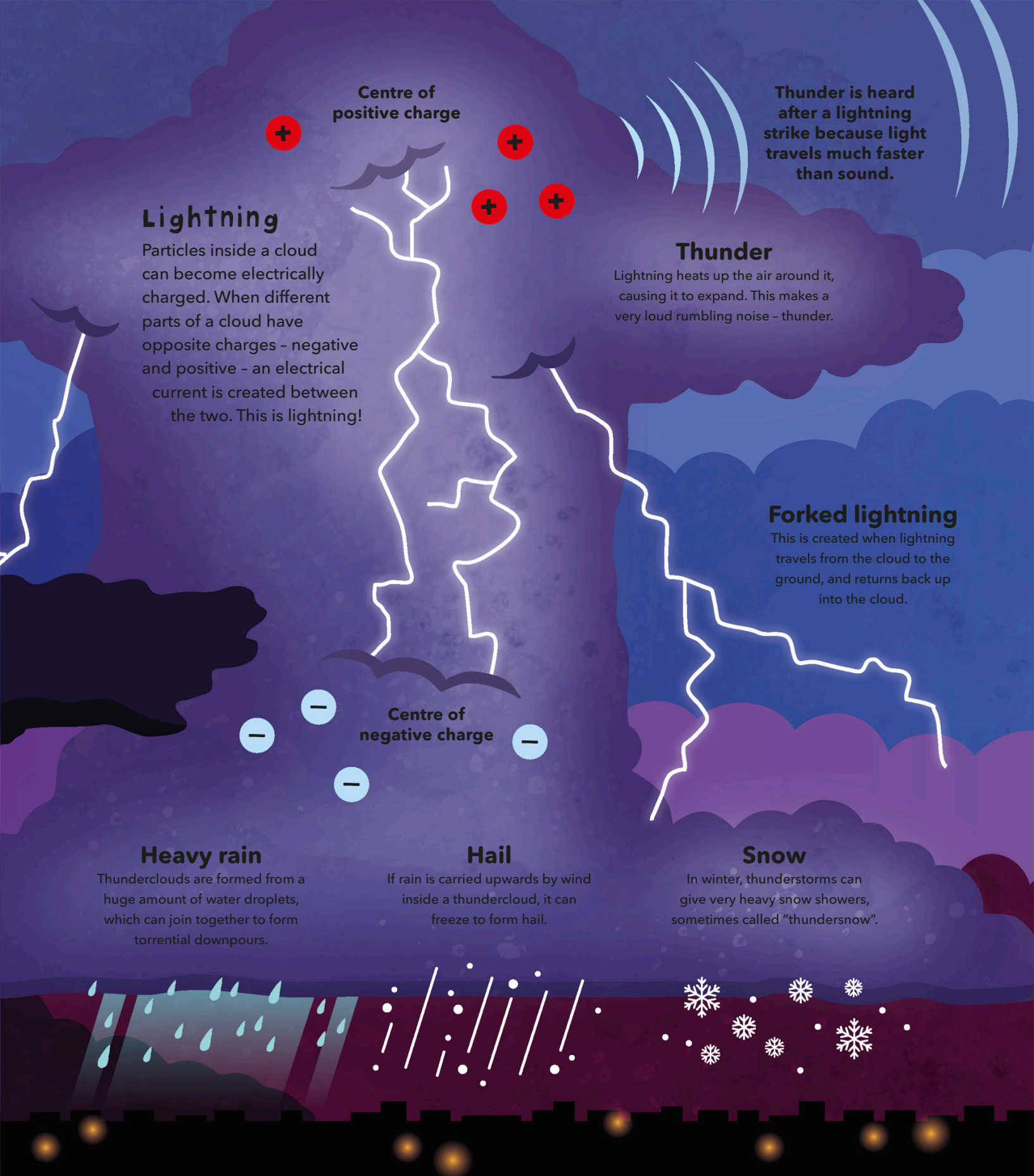
Strong wind

Warm air currents move upwards to build the thundercloud. Cold air sweeps down to give gusty winds.

Lightning strike

Some lightning travels all the way down to the ground from the cloud. It often hits high objects such as trees and mastpoles – but it can strike anywhere.

All the water droplets in a cumulonimbus cloud can



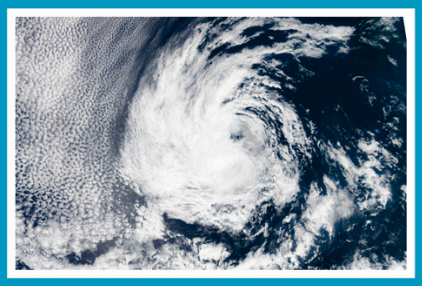
weigh more than 450,000 kg (1,000,000 lb).

Huge storms

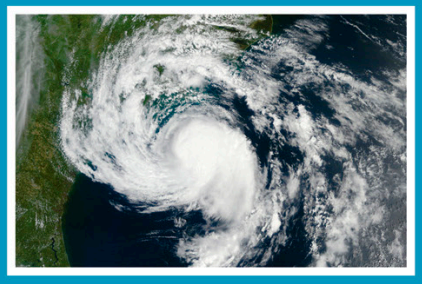
Massive, rotating storms holding enormous power can form over warm oceans. If such storms move overland they can cause a lot of destruction to buildings and trees.

Small to big

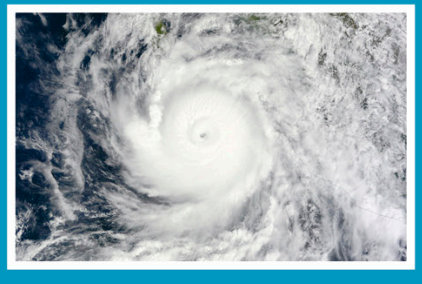
There are three types of storm that form over the ocean, which are defined by their strength. A tropical depression or storm can be the early stage of a more powerful storm.



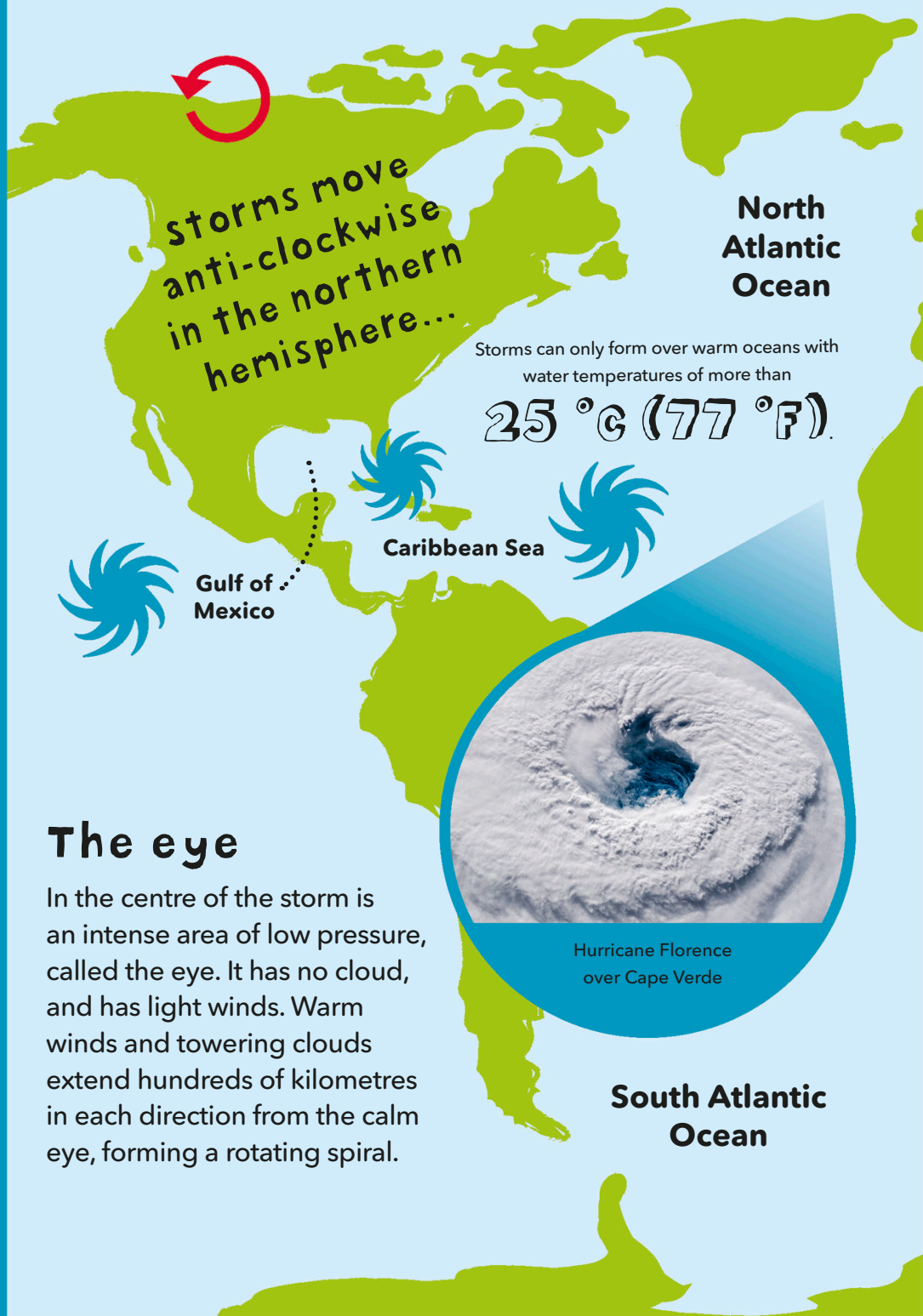
1 **Tropical depression**
These have a wind speed of up to 61 kph (38 mph).



2 **Tropical storm**
The wind speed is about 63–117 kph (39–73 mph).



3 **Hurricane**
Wind speeds reach 119 kph (74 mph) or more!



The eye

In the centre of the storm is an intense area of low pressure, called the eye. It has no cloud, and has light winds. Warm winds and towering clouds extend hundreds of kilometres in each direction from the calm eye, forming a rotating spiral.

Worldwide

There are different names for storms that form over the ocean, depending on the area in which they form.

Hurricane
North Atlantic, Caribbean, Gulf of Mexico, Eastern North Pacific

Typhoon
Western North Pacific and around Southeast Asia, Indonesia, and Japan

Cyclone
Indian Ocean, including the Bay of Bengal and the Arabian Sea, and around Australia

Storms can last many days or even over a week!

Roll call

Storms that form over the ocean are given names so that they can be tracked. Scientists use names beginning with each letter of the alphabet in turn, so it's easy to remember which storm is which.

North Pacific Ocean

Arabian Sea

Bay of Bengal

Indian Ocean

South Pacific Ocean

Storm surge

Powerful storms can produce torrential rain, very strong winds, thunderstorms, and sometimes a storm surge. This is a massive wall of water that can flood coastlines and damage buildings.

...and clockwise in the southern hemisphere.

Snow

The conditions have to be just right for snow to fall. It forms inside freezing clouds from miniscule ice crystals. If you zoomed in on a flake you might find a complicated 3D shape or fascinating pattern.

The right clouds

Clouds need to be full of ice crystals to make snow. Large clouds, such as cumulonimbus, nimbostratus, and altostratus, are often the culprits. Look out for these on a cold day and snow is likely to be on the way.

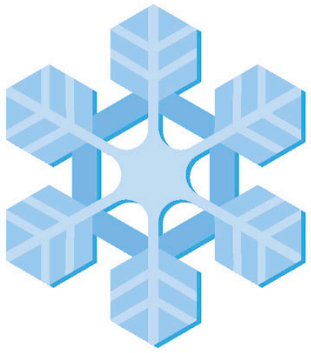
How it forms...

1 Ice crystals

Low temperatures cause tiny droplets of water to freeze inside clouds as ice crystals.

2 Snowflakes

The ice crystals start to stick together to make snowflakes.



The crystals join to form beautiful patterns.

Most snow falls to the ground in temperatures below

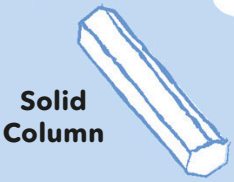
2°C (36°F)

Snow is see-through! Light

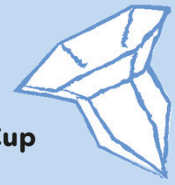
Snowflakes form in lots of different shapes.

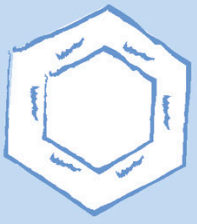
3 Falling snow

The different-shaped snowflakes grow too heavy to stay in the cloud. They fall to the ground.

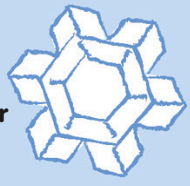

Solid Column

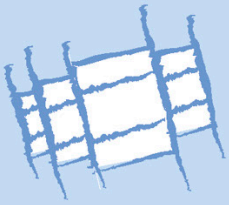
Simple Prism


Cup

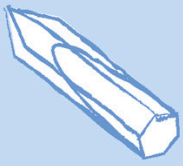

Hexagonal Plate

Capped Column


Stellar Plate


Multiple Capped Column

Triangular Form


Sheath

The snow line

In some places, snow and ice cover the ground above a certain height all through winter – or even year round! This is called the snowline. It is usually on cold mountains, high above the ground.

Capped Bullet

bounces off the flakes' surfaces so it looks white.

For part of the year, snow covers about a third of the Earth's land.

Most in a 24-hour period

According to local reports, **2.56 m (8.4 ft)** of snow fell in one day in Capracotta, Italy, on 5 March 2015. That's about as high as a garden shed.

Deepest snow

Snow on Mt. Ibuki, Japan, was **11.82 m (38.8 ft)** deep on 14 February 1927 – the deepest ever recorded. That's about as high as a two-storey house.

Most in a one-year period

From February 1971 to February 1972, the total snowfall on Mount Rainier, USA, added up to **31.5 m (102 ft).** If it had all fallen at once, it would have just about covered a seven-storey building!

Snow absorbs sound, so it's quieter during snowfall, or just after!

Ice age

The Earth sometimes goes through a long period of time that is very cold – an ice age. This can last for millions of years. The surface might be covered in frozen land, and even frozen oceans!

Snowball Earth

An extreme ice age is thought to have taken place from around 720 to 630 million years ago, creating a snowball Earth! Glaciers may have covered the whole planet. This time in history is known as the Cryogenian period.

Hot, cold, hot...

The Earth has been through at least five long-lasting ice ages. Warmer periods, called greenhouse periods, take place between major ice ages. Greenhouse periods tend to last much longer than ice ages.

Greenhouse period

Ice age

A rise in greenhouse gases in the air is thought to be the main reason the last ice age ended. Greenhouse gases trap heat, which melts ice.

In past ice ages, glaciers were up to 1.6 km (1 mile) thick.

Are we living in an ice age?

Yes we are! We are in the Quaternary Ice Age. However, we are in the warmer stage of an ice age, called the **interglacial** period, when glaciers shrink.

Glaciers

During an ice age, massive areas of thick ice, called glaciers, can cover a third or more of the planet. The ice moves overland like a very slow river. It can pick up rocks and leave them in piles elsewhere. Sharp rocks in glaciers can carve ridges into the landscape.

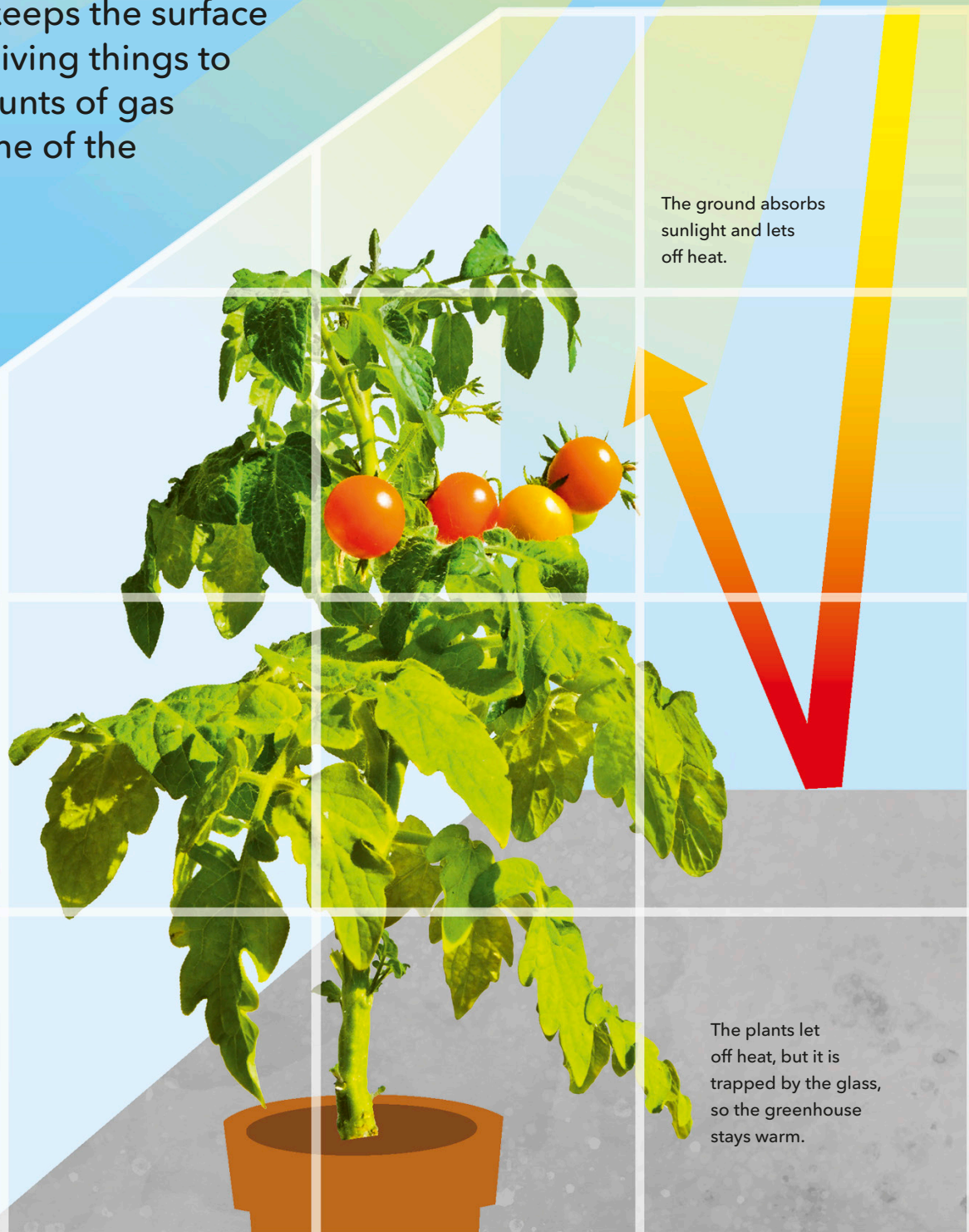
The little ice age

Smaller periods of cooler temperatures can occur, affecting certain parts of the Earth. In Europe, temperatures dipped much lower than normal between 1450 and 1850. The River Thames in London, UK, often froze, and people set up ice fairs on its surface!

It would once have been possible to ice skate from Europe to the USA!

The greenhouse effect

Greenhouses trap heat – just like the air around our planet! Temperatures in space can get very cold. A layer of natural gases around the Earth keeps the surface warm enough for living things to survive. Extra amounts of gas are created by some of the things humans do.

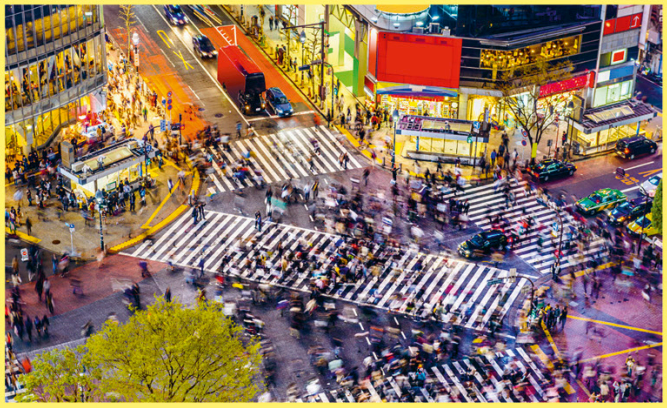


How does it work?

The glass of a greenhouse keeps warm air inside. In a similar way, there is a blanket of gases around the Earth, which stops heat from escaping.

More people, more problems

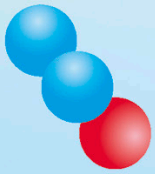
The amount of people on the Earth is increasing. This means more electricity, transport, and factory-produced products are needed. Today, around 80% of power is made using pollution-creating fossil fuels.



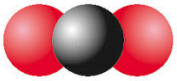
Greenhouse gases

Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) absorb heat. If more of these are created, or if less are taken out of the air, the Earth will heat up more.

Planes produce large amounts of carbon dioxide.



Nitrous oxide



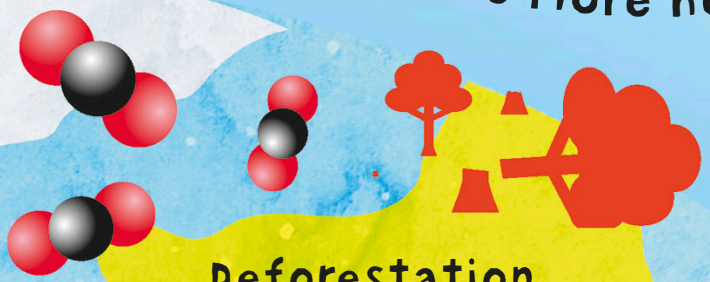
Carbon dioxide

Methane

Pollution

Burning fossil fuels, such as coal, creates greenhouse gases. Many vehicles, factories, and electricity plants burn these fuels to create power.

The more greenhouse gases, the more heat is trapped.



Deforestation

Plants absorb CO_2. Less CO_2 is absorbed if forests are chopped down, which is called deforestation.

Amazon Rainforest deforestation

Heating Up

The Earth was much hotter millions of years ago. It could be freezing cold a million years in the future. The temperature changes naturally over time. However, it has never heated up as fast as it is doing now.

Ever-changing

The Earth's temperature changes for many reasons. Most of these are natural and beyond our control, but some are not.

Solar output

We get most of our heat from the Sun. This means that if the Sun heats or cools, so does the Earth. There has been slightly less heat coming from the Sun in the last few decades. However, the Earth has heated up in that time because of human activity.

Natural cycles

Over the last 2.5 million years, the Earth has gone through hotter and colder periods. The cool ice ages last for around 100,000 years. Warmer, interglacial periods, such as the one we're in now, last for around 10,000 years.

Ice Age mammoth

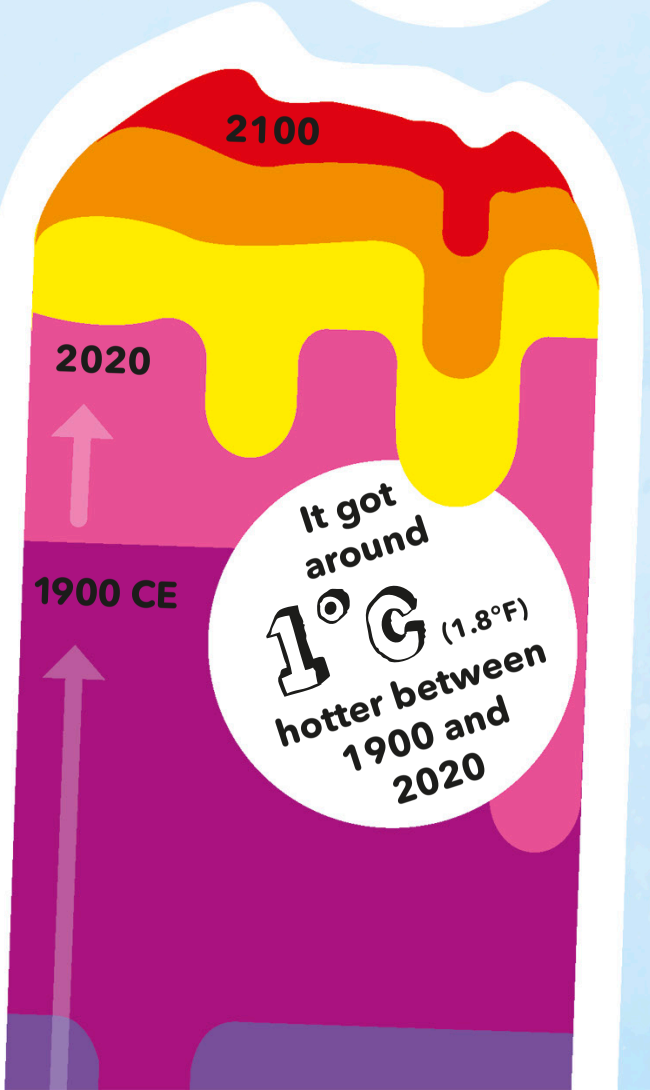
Greenhouse gases

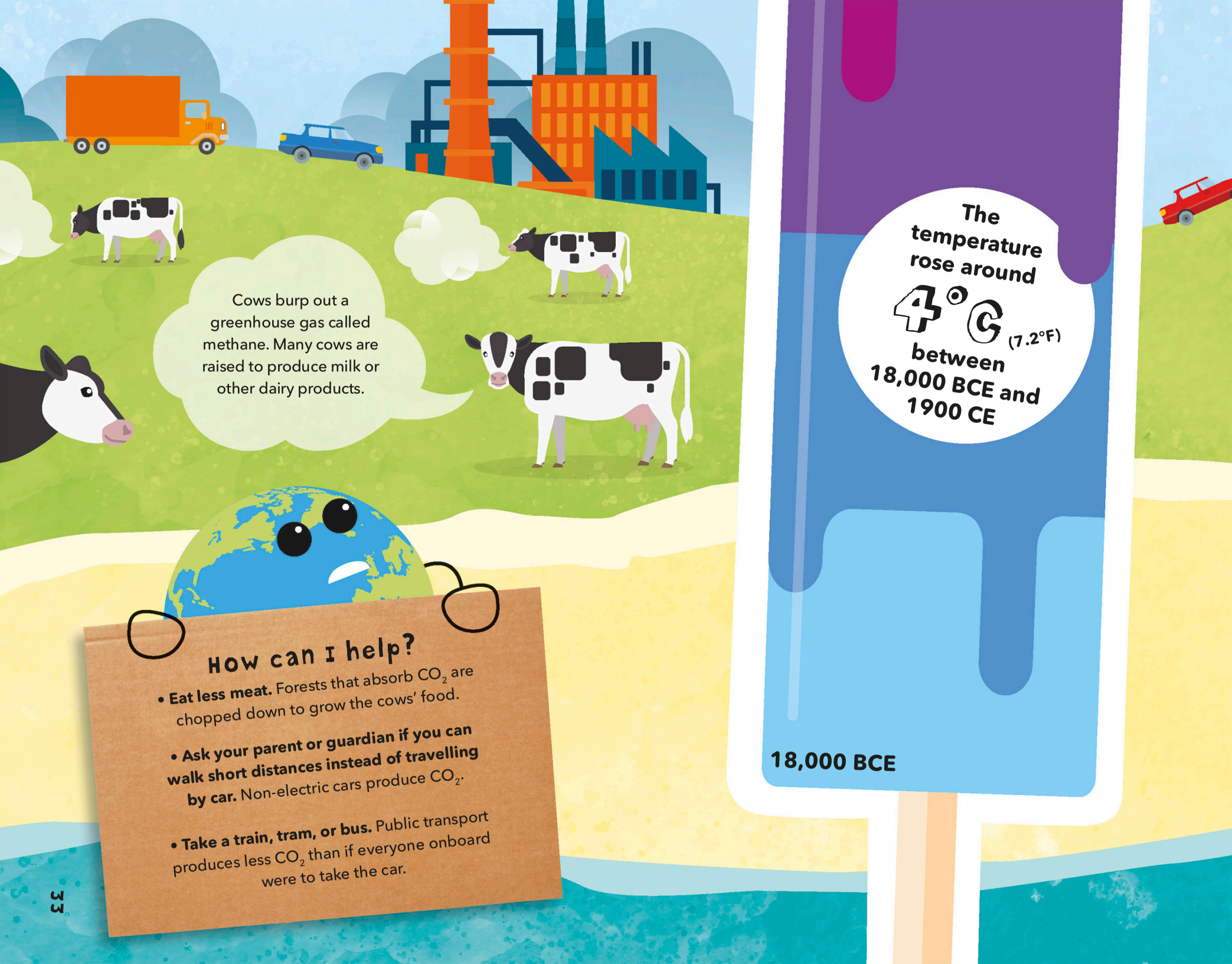
A layer of gases around the Earth absorbs the Sun's heat and acts like a blanket, keeping our planet warm. Human activity increases greenhouse gases, such as carbon dioxide, or CO_2.

Getting warmer

It usually takes thousands of years for the Earth to heat by one degree. We are now heating at a much faster pace.

It could get around 3°C (5.4°F) warmer by 2100




Cows burp out a greenhouse gas called methane. Many cows are raised to produce milk or other dairy products.
The temperature rose around 4°C (7.2°F) between 18,000 BCE and 1900 CE
18,000 BCE
How can I help?
• Eat less meat. Forests that absorb CO_2 are chopped down to grow the cows' food.
• Ask your parent or guardian if you can walk short distances instead of travelling by car. Non-electric cars produce CO_2.
• Take a train, tram, or bus. Public transport produces less CO_2 than if everyone onboard were to take the car.

Solar farms tend to be built in very sunny places, such as deserts.

The International Space Station uses solar panels.

Solar

Sunlight can be collected and turned into electricity using solar cells. Many solar cells are packed together in a solar panel. Large groups of solar panels can produce enough electricity for many homes.

Tiny solar panels can power small devices, such as radios.

The Desert Sunlight Solar Farm, in the Mojave Desert, USA, can provide enough electricity for 160,000 homes.

Weather

Wave

Winds blowing across oceans create waves. Every wave carries a lot of energy, which can be used to power machinery that creates electricity.

3. As the turbines turn, the generator turns the energy into electricity.

2. The arms pump the water through turbines.

1. The waves push the arms up and down.

The Sun's heat and the wind's strength can be used to power machinery to make electricity. This is clean energy – meaning it doesn't produce dirty fumes or increase global warming.

power

solar thermal

The Sun's energy can be used to heat fluid, which creates steam that turns turbines to make electricity. The sunlight is collected using mirrors.

Huge plants with thousands of mirrors collect sunlight for solar-thermal electricity.

The combined sunlight from the mirrors is used to heat fluid in the tower.

Mirrors focus sunlight onto a tower in the middle.

wind

Tall turbines are used to harness the power of the wind. The wind turns massive blades on the turbine, which turns machinery to create electricity. Wind turbines are often placed together at windy spots to generate lots of electricity.

The tops of hills are good places for turbines because there is nothing around to block the wind.

Around 80 countries use wind power as one of their main sources of energy.

Turbines in the ocean float on platforms, or are anchored to the seabed.

Small turbines can provide electricity for homes.

Drought

An area can become much drier than normal over a long period of time. This is called a drought. It can affect farming and water sources, and the people who need them.

There needs to be plenty of rain in order for plants to grow, such as the crops we use for food. However, conditions need to be right for it to keep raining...

Meteorological drought

Long periods with very little or no wet weather are called meteorological droughts. They can end suddenly.

Hydrological drought

Lack of rainfall can cause rivers, streams, and reservoirs to become low. This is a hydrological drought. It may affect people who rely on the water source.

Since 1900, more than 11 million people have died as a result of drought.

If the humidity and air pressure change, clouds can't form to give us rain. The ground dries out and plants can die. This might last for months or even years.

Wildfires

Dry weather can lead to fires in forests and bushes.

Why they start:

The Sun can start fires in dry areas, such as those during droughts.

If a storm breaks a dry spell, lightning can start fires.

What happens next:

Strong winds can fan fires out of control.

Rainfall can help extinguish fires.

Moisture on the ground from recent rainfall can stop fires.

Agricultural drought

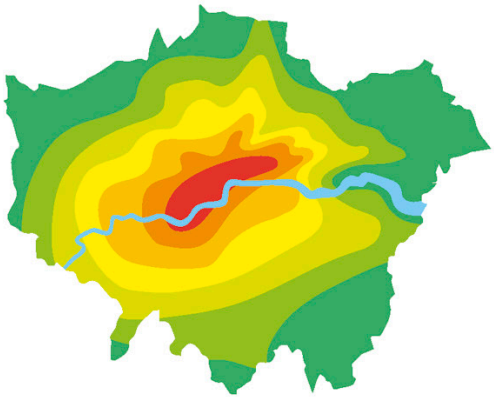
When crops die due to a drought, it is called an agricultural (farming) drought. Some plants are affected by a lack of rainfall after just 15 days.

Socioeconomic drought

A drought that affects humans is called a socioeconomic drought. For example, farmers might have no crops to sell during a drought.

Heat island

A mass of warm air can form over a large city, often when there is little wind. This is caused by buildings and roads absorbing heat, as well as the heating supplied to homes, offices, and shops seeping out.



London, UK, often gets hotter the nearer you are to the centre.

Clouds and rainfall

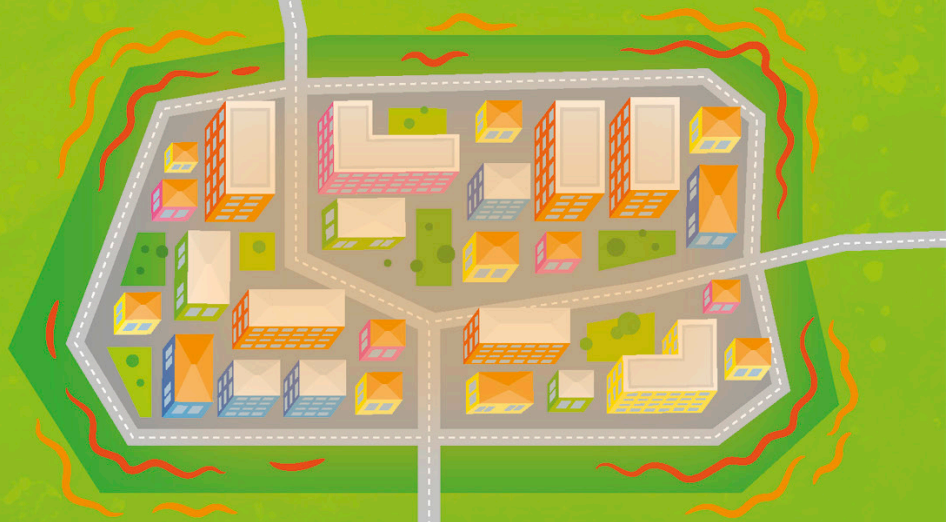
The "heat island" effect causes warm currents of air, which rise and cool to create bigger shower clouds. This often happens in summer, when heavier showers in cities can cause flash flooding.

City microclimates

The weather and climate over a small area can be different from that all around it. This is called a microclimate. It can occur naturally, or as a result of buildings and roads. Major cities can experience a microclimate due to their size, the height and heating of buildings, traffic, and more.

Hot weather

The "heat island" effect can cause temperatures of up to 6°C (10.8°F) hotter in the city centre than in outer suburbs. At night, some city centres have recorded temperatures of up to 11°C (19.8°F) warmer than in the nearby countryside!



When it is windy, the temperature difference is much smaller!

Haze

Exhaust fumes from busy traffic, factory fumes, and heating and air conditioning for buildings are all air pollutants. These can combine to cause a haze, or even a thick smog, over cities.

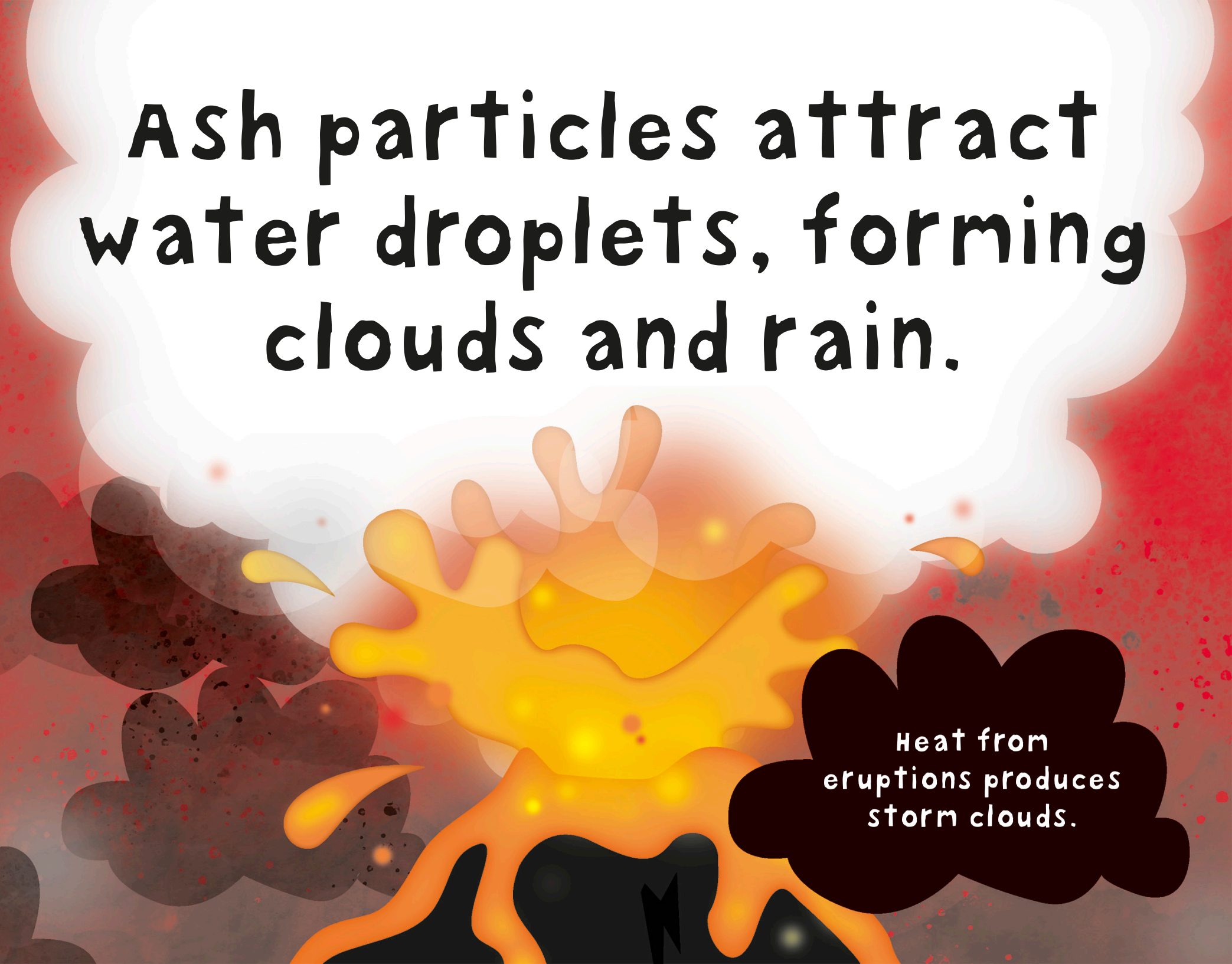
Snow and frost

You are less likely to see snow or frost covering the ground in city centres, even when surrounding areas have it! This is because of the warmer conditions there, caused by the "heat island" effect.

Wind hitting a skyscraper can be channelled down to the ground below.

Windy

Large buildings block the wind so it moves around them, making it less windy behind the buildings. However, the streets either side are made windier, instead! Tall buildings arranged in blocks can direct the wind into streets to make them very gusty.


Ash particles attract water droplets, forming clouds and rain.
Heat from eruptions produces storm clouds.

From 1783–1784, the Grímsvötn volcanic system in Iceland erupted in a series of explosions. Massive amounts of a gas called sulphur dioxide were spewed into the air. The gas combined with water vapour to form a poisonous sulphuric-acid mist.

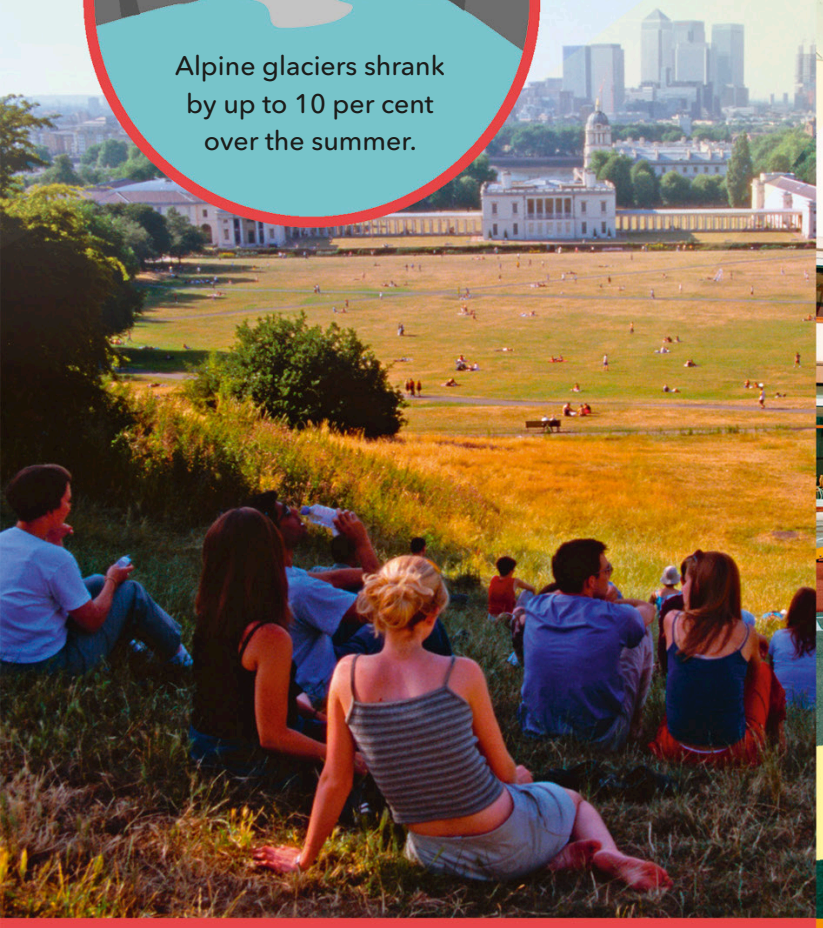
The 1991 eruption of Mount Pinatubo, in the Philippines, was linked to cooler weather worldwide, with temperatures lowered by about 2°C (3.6°F). Brilliant sunrises and sunsets took place, as volcanic dust split light into different colours in the sky.

The Icelandic volcano Eyjafjallajökull erupted in 2010, throwing out so much dark ash that air travel was severely disrupted. Ash inside clouds fell to the ground within raindrops. The Sun was blocked by the ash, causing cooler temperatures.

Heatwaves

When weather that's hotter than normal continues for a few days, weeks, or even months, we call it a heatwave. Heatwaves are most common in temperate climate areas.

Alpine glaciers shrank by up to 10 per cent over the summer.



Western Europe

A heatwave hit Europe from June to August in 2003. It was partly caused by high pressure, which stops clouds forming. It was the continent's hottest summer on record since 1540.

Approximately 4,000 French schools shut nationwide.

France

Very hot air from the Sahara Desert moved north over Europe in late June 2019, causing a heatwave in France. A temperature of 46°C (115°F) was recorded – the country's highest ever.

Big freezes

Unusually cold weather can stretch for a long period of time – sometimes lasting through winter. Snow and ice might cover the landscape in temperate zones that don't often see such cold weather!

It was so cold that jet fuel froze at Chicago O'Hare Airport.

The UK

The UK's coldest winter on record was from December 1962 to February 1963. Snow lasted for two months in many places, and the Thames Estuary froze around Herne Bay in Kent!

USA and Canada

In January and February 2014, ice-cold conditions froze parts of the Hudson River, in New York City. The cold weather reached the usually mild Deep South, causing frost in parts of the state of Florida.

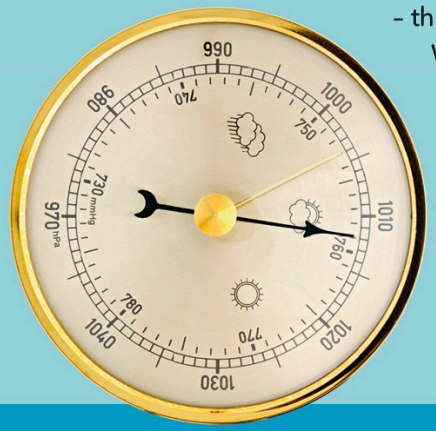
Inventions

Many machines have been invented over time to measure and record the weather. Clever gadgets can tell us everything from how fast the wind is blowing, to how much rain or snow is falling in the distance.

1643

The Barometer

This gadget measures air pressure – the pushing force of the air. When pressure is high, the air squeezes the machine and the arrow points to a high number. When pressure is low, the machine expands out and gives a lower number. The pressure can be used to forecast how strong the wind will be.



1896

The Weather Balloon

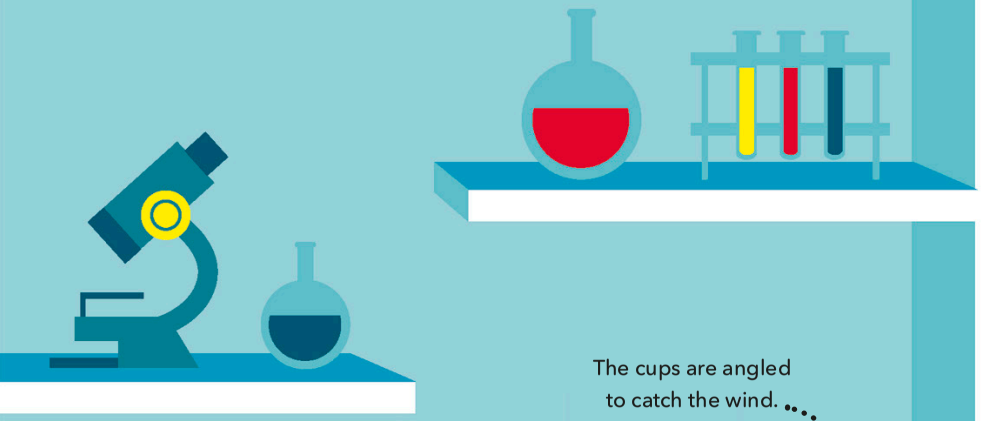
Weather balloons carry equipment into the sky to measure weather. The balloon grows from 2 m (6.6 ft) wide to a massive 10 m (33 ft) as it rises. It bursts and falls back to Earth when it reaches the edge of space!

A cord carries instruments that record the air pressure, wind speed, humidity, and temperature.

1894

Lightning Detection System

This invention tells people where lightning is striking. There are systems on satellites in space, on the ground, and on aircraft. The lightning can be plotted on a digital map to show the movement of storms.

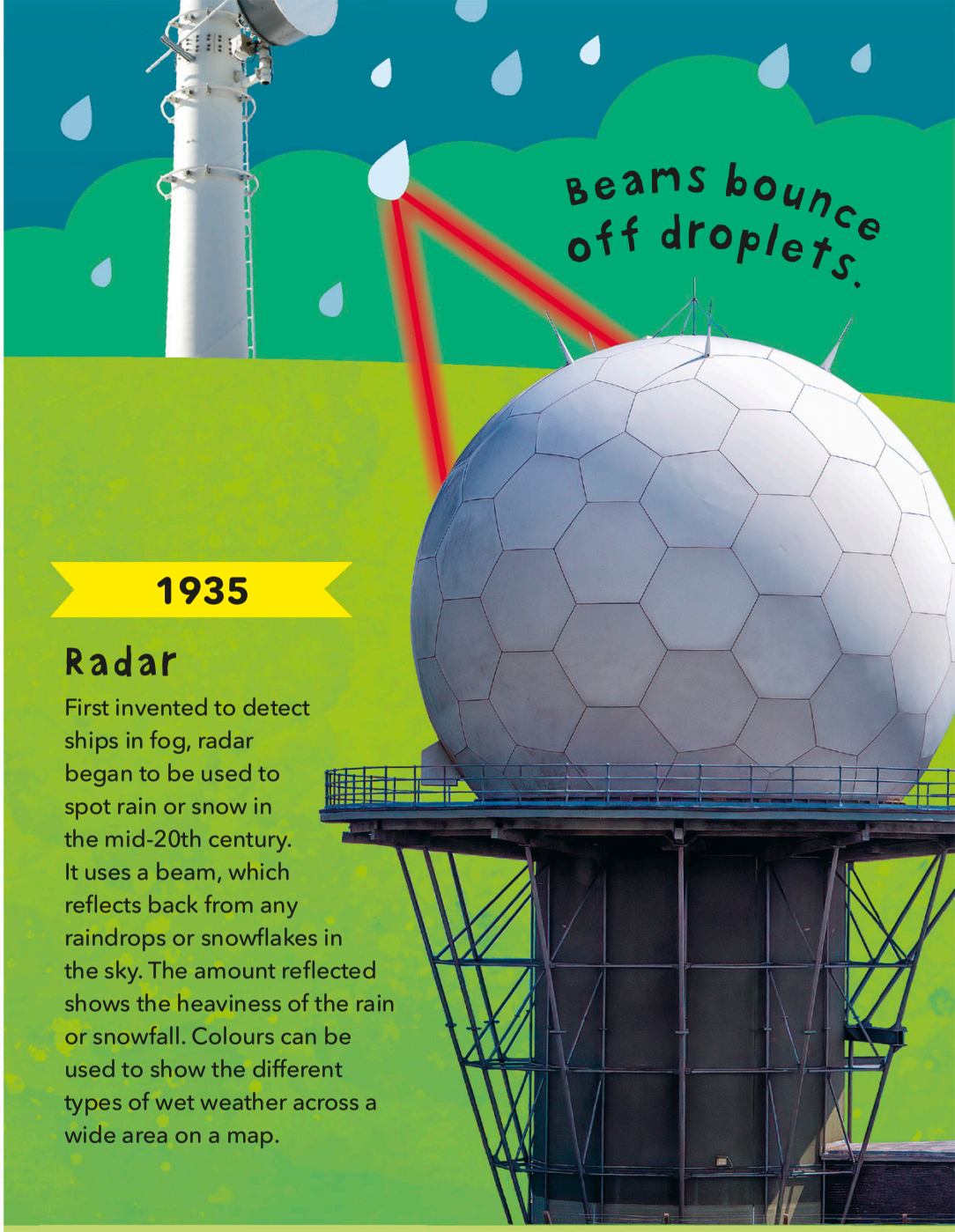


The cups are angled to catch the wind.

1450

Anemometer

Wind speed can be measured using an anemometer. The most common type uses metal cups mounted on a spindle on a mast. The number of times the cups spin around per second shows the wind's speed.



Beams bounce off droplets.

1935

Radar

First invented to detect ships in fog, radar began to be used to spot rain or snow in the mid-20th century. It uses a beam, which reflects back from any raindrops or snowflakes in the sky. The amount reflected shows the heaviness of the rain or snowfall. Colours can be used to show the different types of wet weather across a wide area on a map.

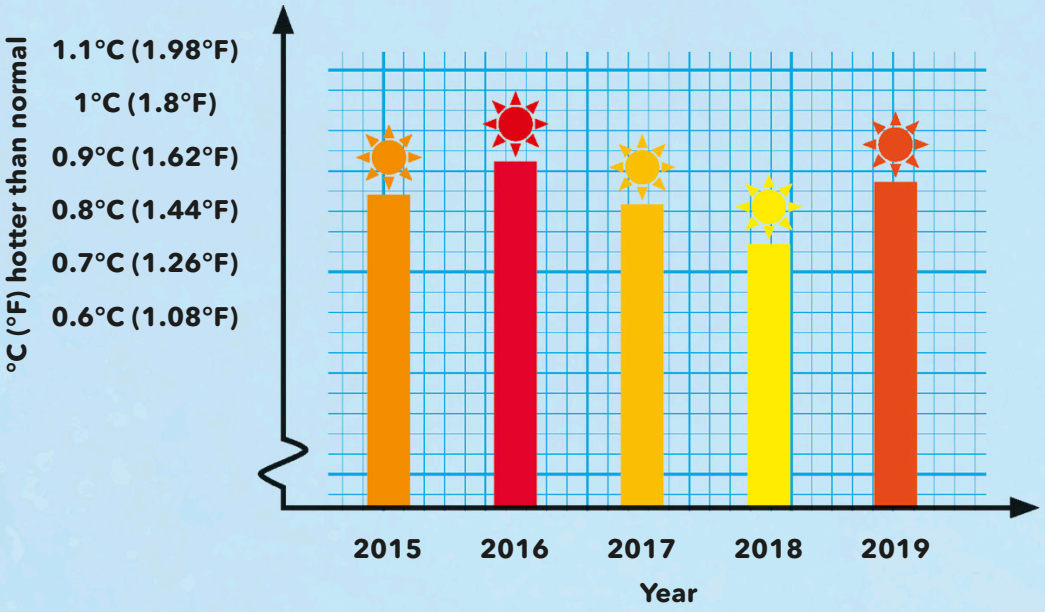
The weather news

People often talk about the weather, especially if it is out of the ordinary. Single events can cause huge damage or strange happenings, which get reported around the world.

In the past, frogs have fallen from the sky! They were probably carried up by tornadoes.

Hottest years

Scientists keep track of global temperatures, so they know when a year is hotter than normal. Since 2015 we have experienced the five hottest years since records began, in around the mid 1800s. Find out why this might be on pages 32–33.



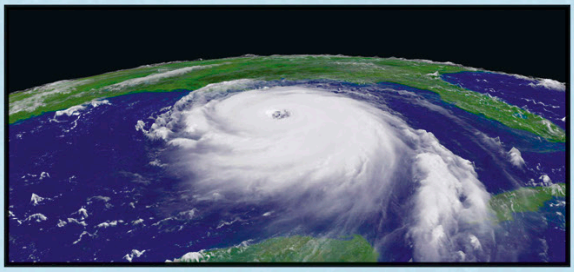
A flooded Canvey Island, England

North Sea flood

A huge storm surge took place in 1953. It was caused by strong winds, low pressure, and high tides – during which the ocean reaches further inland than normal. The swell of water travelled down the North Sea, flooding large areas of eastern England. Across the sea, in the Netherlands, coastal walls were destroyed and towns were flooded.

Hurricane Katrina

This enormously powerful hurricane was one of the most damaging in history. It developed across the Gulf of Mexico and lasted for eight days. The city of New Orleans, USA, was badly affected. Flooding broke through its levees (raised strips of land to prevent floods). Up to 80 per cent of the city was under water for weeks.



Satellite image of Hurricane Katrina

New Orleans under water

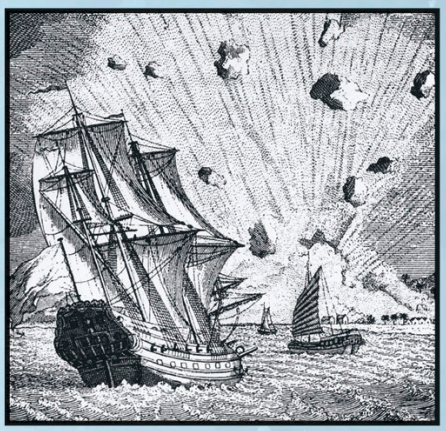
In 1992 a hurricane in Miami, USA, damaged a building containing snakes – freeing hundreds!

Ice Storm

Very cold air can causes objects at ground level to freeze. If it begins to rain, the drops of water instantly freeze when they hit the object. This can cause buildings and cars to become encased in glittering white ice! Spray from lakes or oceans can freeze on objects in the same way during very cold weather. The picture above shows a lighthouse in Michigan, USA, covered in frozen ocean spray.

Year without a Summer

In April 1815, Indonesia's volcanic Mount Tambora erupted. An enormous ash cloud was sent up into the sky. It spread out and circled the globe. The thick, grey cloud blocked the Sun's rays and lowered world temperatures by 3°C (5.4°F).



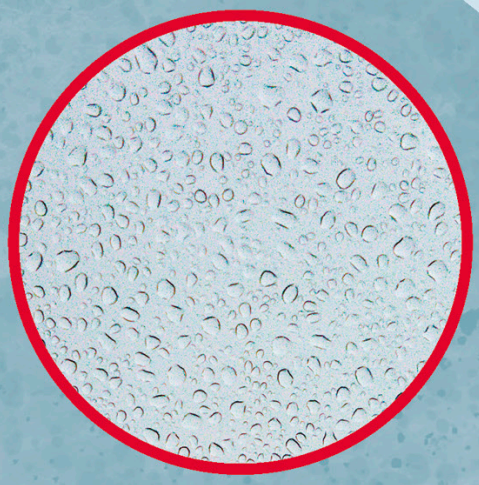
The eruption

Fog

Fog is a like a grey cloud hovering just above the ground. It can make it hard to see, sometimes blocking out what's right in front of you. This makes it troublesome for travellers!

What is fog?

Humid air contains lots of water vapour – the gas version of water. Fog is formed when this air is cooled from below, causing the vapour to turn into droplets.



Fog is made up of tiny droplets of water. Sometimes tiny ice crystals are also found in fog.

Fog can occur if rain wets the ground and clouds clear at night.

Land fog

Fog is common over ground in autumn and winter, during clear, starry nights with little wind. It often forms over marshy ground or near ponds, lakes, or rivers. At sub-zero temperatures it is called freezing fog.

Ocean fog

This forms when warm, humid air drifts over a cool sea. It is most common in spring, when the ocean is still quite cold and the air becomes warmer.

Smog

Fog can combine with air pollution from traffic or factories that burn fuel to power machinery. This is called smog. It was common in cities around the world until the 1960s, when many countries passed laws against producing certain kinds of pollution.

Fog can form in valleys when cold air sinks at night.

Thick fog is a hazard to road, air, and sea traffic.

Mist is a less thick version of fog.

Foghorn

Before digital maps were invented to tell us where we are, people needed a clever way to navigate through fog. Foghorns were designed to let out a blast of sound, so boats knew they were approaching land or another ship.

In the rainforest

Tropical rainforests gain more energy and heat from the Sun than anywhere else on Earth. The weather is reliable and repetitive. High humidity, heat, and heavy rainfall create plentiful plants. The plants grow big in the year-round wet weather.

Trees grow up past each other to find sunlight. They can reach heights of up to 88.5 m (290 ft) – about as high as 10 two-floor houses piled up!

There are about 100 different species of rainforest tree. Many more plants grow on and around them.

At midday it is around 30°C (86°F).

Morning

As the Sun rises, the temperature quickly rises. Cumulus clouds start to develop.

Early afternoon

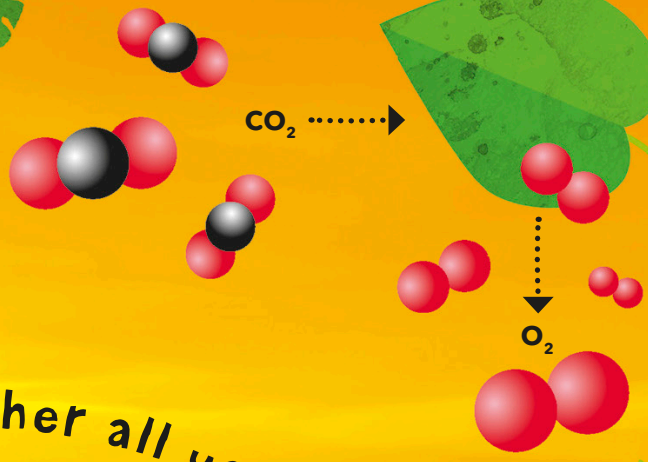
The humid heat constantly rising from the ground causes the cumulus clouds to grow bigger.

Where in the world?

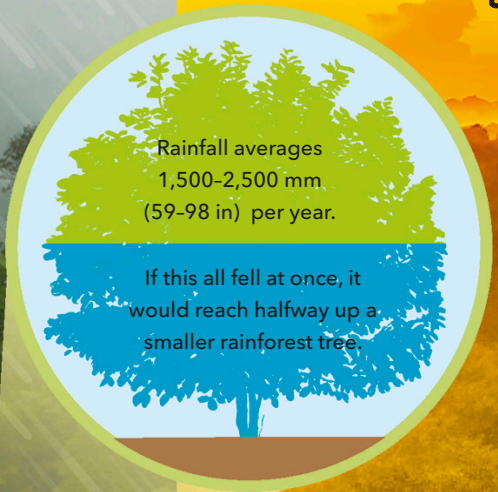
Tropical rainforests occur in countries near and along the Equator, such as Ecuador, Brazil, Congo, and Indonesia.

Important plants

Plants take the gas carbon dioxide (CO_2) out of the air to make their food. This gas traps heat, and lots of it can warm our planet too much. Plants also release oxygen (O_2), which we breathe!



Rainforests have similar weather all year round.



Rainproof plants

Too much water can be bad for plants! Rainforest plants quickly release water through their leaves, and are shaped so that rain runs off them.

Late afternoon

Torrential showers start to fall and thunderstorms rage, often at the same time every day!

Evening

The weather becomes dry by around sunset. The nights are less cloudy and never cold, but they can grow misty.

In the past, people lacked the technology to measure weather.

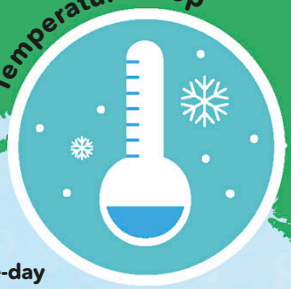
Record breakers

What's the hottest day you can remember? Have you ever seen a gigantic hailstone? Here are some of the most incredible, record-breaking weather events from around the world.

North America

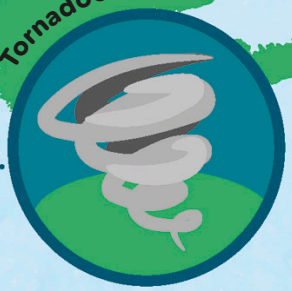
South America

Temperature drop



During the **biggest one-day temperature drop**, it got a chilling 56°C (100°F) colder, from 7°C (44°F) to -49°C (-56°F).

Tornadoes



"Tornado Alley", USA, catches the **most tornadoes** every year – around 1,000 a year!

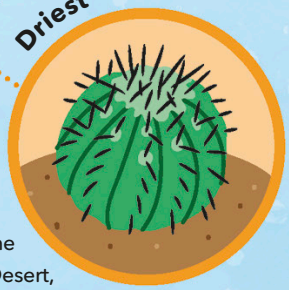
Hottest

The **hottest temperature** recorded was in Furnace Creek, USA, at 56.7°C (134°F) – hot enough to fry an egg on the ground!

Thunderstorms

Lake Maracaibo, Venezuela, has the **most thunderstorms,** with up to 28 lightning flashes a minute.

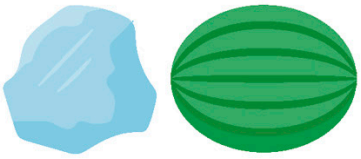
Driest



A part of the Atacama Desert, Chile, is the **driest place** outside the Poles, with only 0.2 mm (0.007 in) of rain a year.

cold wonders

The **biggest snowflake** recorded measured 31 cm (15 in) wide - around the size of a large pizza.



The **largest hailstone** on record measured 47 cm (18.5 in) in circumference – about as big as a watermelon.

The **heaviest hailstone** weighed around 1 kg (2 lb), which is the same as a big bag of flour.

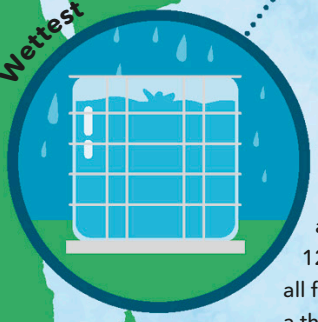
Europe

Asia

Africa

Australia

Wettest



Maysynam, India, is the **wettest place**, with an average rainfall of 12.7 m (41.7 ft). If the rain all fell at once, it would cover a three-floor building!

The **highest wind speed** recorded was a gust of 407 kph (253 mph) – as fast as most racing cars!

Wind speed

People began recording weather properly in the late 1800s.

Coldest

The **coldest temperature** on record was in Antarctica – a low of -89.2°C (-128.6°F).

In a part of Antarctica, there has been **no rain at all** for almost 2 million years.

Rainless

Weird Weather

Of the many different types of weather around the world, some are more unusual than others. A moving wall of sand can appear, strange snow might carpet the streets in colour, and small vegetables can affect the weather! Have you experienced anything quite like these weird weather events?

Mushroom rain

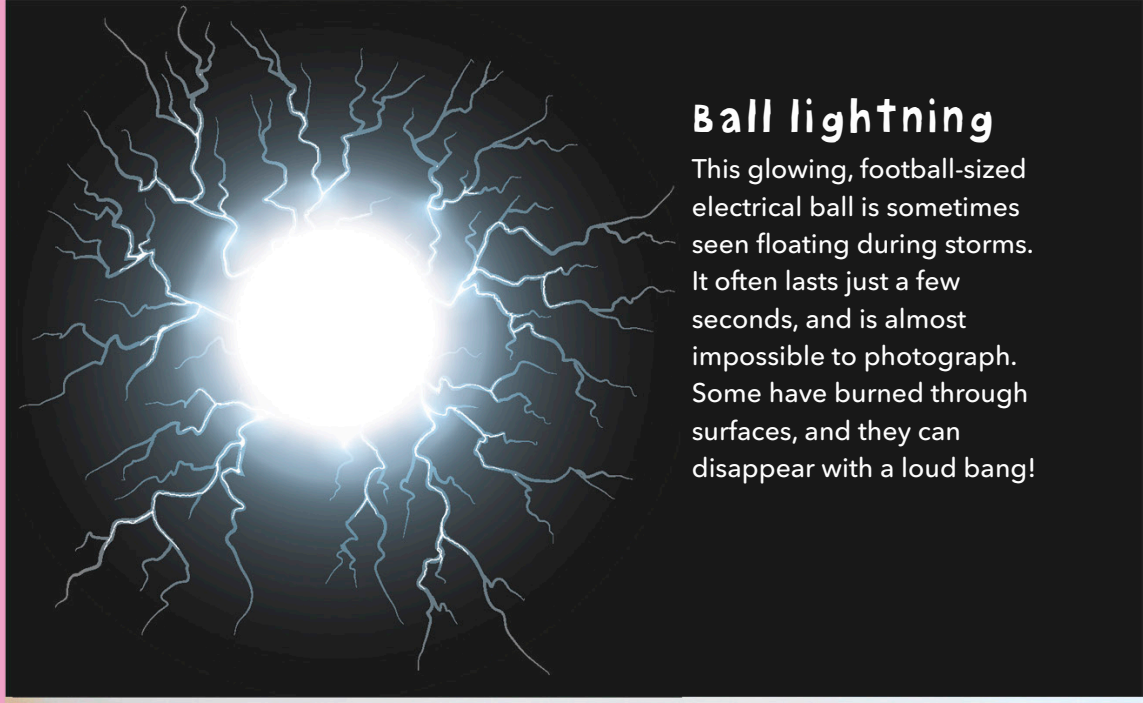
Mushrooms need moist ground to grow, so they have learned to make rain themselves! They release millions of spores, which float through the air and attract water to form around them, making large raindrops.

Coloured snow

In Stavrapol, Russia, villagers once awoke to a blanket of pink and brown-coloured snow. Scientists confirmed that dust from the Saharan Desert had transformed the snowflakes. Elsewhere in the world, black snow has fallen in Alaska and Canada due to ash from a volcanic eruption!

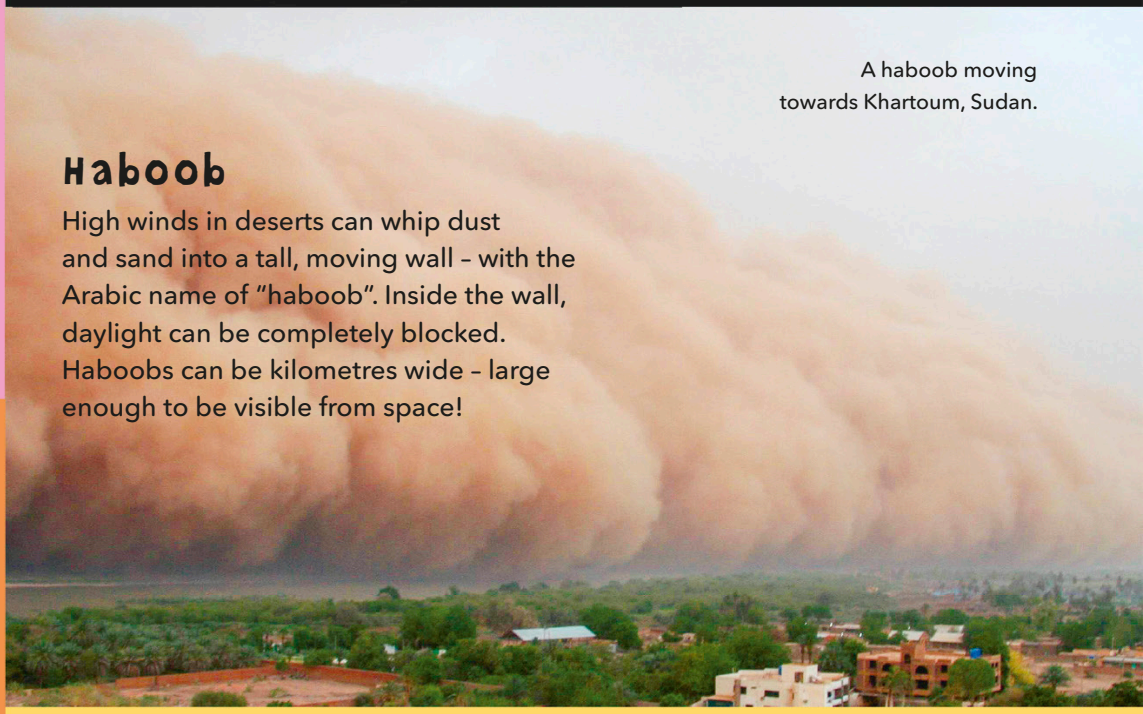
It is thought that coloured snow can be caused by other things besides dust, such as pollution.

Rain forms around spores, as it does with other particles.



Ball lightning

This glowing, football-sized electrical ball is sometimes seen floating during storms. It often lasts just a few seconds, and is almost impossible to photograph. Some have burned through surfaces, and they can disappear with a loud bang!



A haboob moving towards Khartoum, Sudan.

Haboob

High winds in deserts can whip dust and sand into a tall, moving wall – with the Arabic name of "haboob". Inside the wall, daylight can be completely blocked. Haboobs can be kilometres wide – large enough to be visible from space!

Foam attack

When seas are stormy, the tops of waves can be whipped into a sticky foam. This can be blown ashore, and cover coastal roads and even houses in an ocean-made bubble bath!

Foam pouring over the pavement in Hove, UK.

Wood frog

During winter in North America, wood frogs allow two-thirds of their bodies to freeze, like a frog-shaped ice lolly. They produce antifreeze that prevent other parts of their body from freezing, which would be harmful.

Wood frogs hunker down for the winter under leaves.

I can survive for seven months in temperatures as low as **-18°C (0°F)**.

They don't breathe and their heart stops.

Weather-proof animals

Emperor penguin

These birds live in one of the coldest places on Earth – Antarctica. They stand in huge huddles to share body warmth, taking turns to go to the outside layer and shelter the penguins on the inside from freezing winds.

Layers of feathers keep icy winds out.

Thick layers of fat protect them from the extreme cold.

Penguins sit on their eggs to keep them warm, using their own fat as food.

Kangaroo rat

In hot deserts, every breath, drop of sweat, and pee loses water from an animal's body. Desert-living kangaroo rats in North America save water inside them. They can go their whole life without drinking any!

Kangaroo rats have an oily coat that stops sweat being released.

Their pee is highly concentrated to save water.

When breathing, no moisture comes out of their nose.

Their bodies can get enough water from seeds to survive.

You might put on a coat when it's cold, but animals have built-in features to protect them from the weather. Some creatures can survive the high heat of a sandy desert, and others the icy winds and deep snow of the South Pole.

I can survive in temperatures as cold as

-200°C (-328°F).

Tardigrade

These tiny, eight-legged animals are about 0.5 mm (0.02 in) long. They live all over the world, including in places too cold for any other animals to survive.

Tardigrades can dry up into a 'tun' state to survive, in which they need very little oxygen.

Some tardigrades form an extra layer of skin to protect them against cold temperatures.

The biggest tornado in history grew to 4.2 km (2.6 miles) wide.

Tornadoes

Tornadoes are violently spinning columns of air that only take place in special conditions. It is not known exactly how they form. However, weather experts have come up with possible explanations, such as this one.

Tornadoes start to grow below giant cumulonimbus clouds. The air needs to be humid and warm near the ground, and very cold and less humid higher up. The warm air starts to move upwards in draughts, called updraughts.

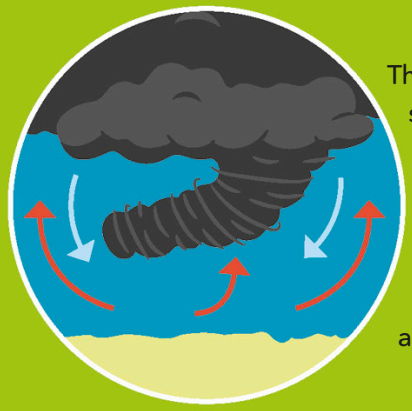
Most tornadoes form in the USA - there are around 1,000 a year.

The Fujita Scale

5
4
3
2
1
0

This scale is used in countries such as the USA to measure the power of a tornado by the damage it causes. The scale rises from 0, for light damage, to 5, for incredible damage.

Tornadoes can lift animals and cars.



The updraughts get stronger, and colder downward currents called downdraughts develop. The updraughts start to spin, forming a funnel cloud.

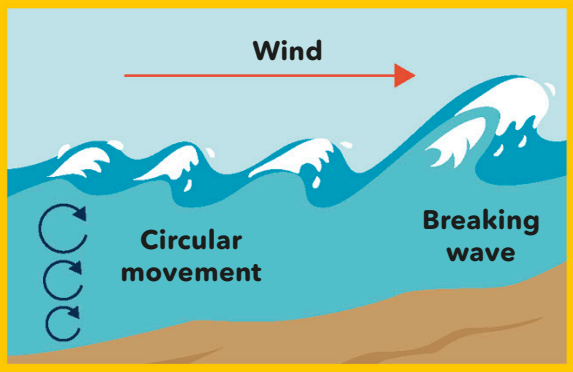
The downdraughts get stronger, and help lower the spinning funnel cloud towards the ground. When it touches the ground it becomes a tornado, which sucks in dust, debris, and more.

Making waves

We can't see wind – but sometimes we can see its effects. Out at sea, the weather is often very windy, which leads to waves. You can tell how windy it is out at sea by looking at the size of waves!

How waves work

The wind blows the surface of the water so that it begins to rotate. The waves move forwards. If the ground under the sea rises, the waves are pushed up and may eventually break.



Large waves can cause sea walls to collapse, remove enormous amounts of sand from beaches, and erode (wear away) cliffs.

Calm

Wind speed
Less than 2 kph (1 mph)
Wave height
0 m (0 ft)
Sea state
Glassy smooth

Light breeze

Wind speed
9 kph (6 mph)
Wave height
0.3–0.6 m (1–2 ft)
Sea state
Slight

Moderate breeze

Wind speed
24 kph (15 mph)
Wave height
1–2 m (3.5–6ft)
Sea state
Moderate

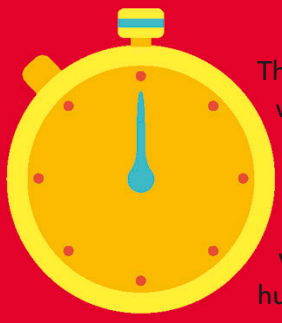
Strong breeze

Wind speed
44 kph (28 mph)
Wave height
3–4 m (9–13ft)
Sea state
Rough

Ingredients

Different ingredients go into building the perfect wave.

Light winds produce small waves. Stronger winds can build much larger ones.



The longer winds blow, the bigger waves become. Days of strong winds can build huge waves.

Shipping forecast

Very large waves are a danger to ships and might even sink them! A special weather forecast tells sailors what the weather out at sea will be like. It includes the sea state, wind details, and visibility.

The largest wave surfed was around 24 m (78 ft) high.

Gale

Wind speed
69 kph (43 mph)
Wave height
5.5–7.5 m (18–25 ft)
Sea state
Very rough to high

Storm

Wind speed
96 kph (60 mph)
Wave height
9.0–12.5 m (30–41 ft)
Sea state
Very high

Hurricane

Wind speed
118 kph (74 mph) or more
Wave height
14+ m (46+ ft)
Sea state
Phenomenal

The wind direction is important. Winds blowing towards land cause bigger waves.

Waves are bigger in very deep water. However, they are also pushed up as they reach shallow water.

The surface of the seabed affects waves – raised coral reefs push waves up, so the waves break in barrel shapes.

Future weather

The climate and weather will keep changing naturally as time goes on. However, many scientists think that human activity will cause more extreme changes. No one knows for sure, but scientists can predict what may happen.

The Sun sends out some harmful rays. Most are absorbed by ozone gases.

Some chemicals cause holes in the ozone layer.

The biggest ozone hole is over the South Pole. It affects wind, rainfall, and temperature across the southern hemisphere. However, old holes are closing.

Factory fumes can trap heat.

Extreme weather

Gigantic storms, heatwaves, forest fires, and other weather that is unusual today may be much more common by the mid 2100s.

Drought

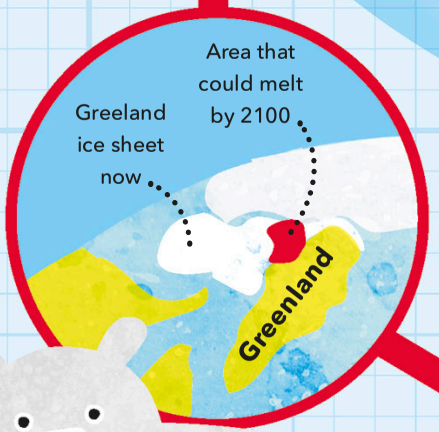
Areas with little rainfall may catch even less rain, making droughts longer-lasting.

Greenhouse gases

If the current greenhouse effect continues, there could be big changes to the world's weather. You can learn more about the effect on pages 30–31.

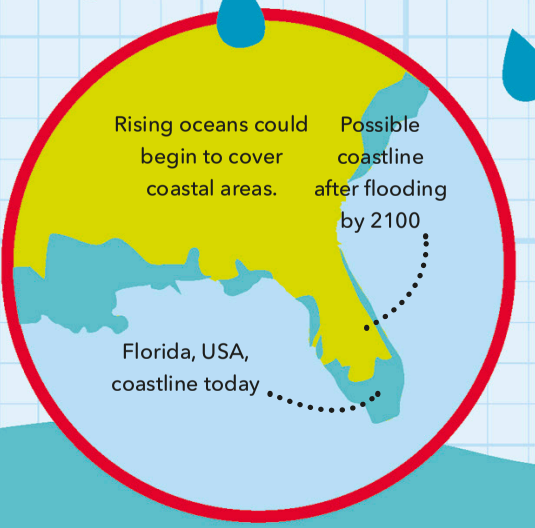
Melting ice

Global warming could quickly cause further melting of the Arctic sea ice, the Antarctic and Greenland ice sheets, and mountain glaciers. The melted ice could enter the oceans.



Rising oceans

Melted ice sheets and glaciers could cause oceans to rise. Higher temperatures could heat oceans, causing the water to expand further.

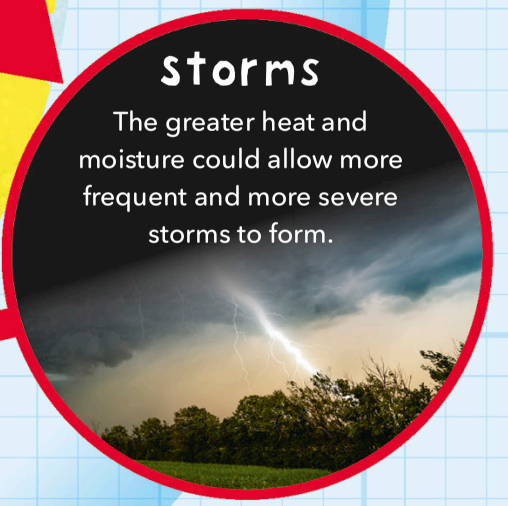


A warmer atmosphere holds more moisture and allows heavier rainfall...

...an increase in floods.

Storms

The greater heat and moisture could allow more frequent and more severe storms to form.



Making changes

People are working hard to stop global warming from causing more extreme weather. Here are some of the things they are doing.

1 Using clean energy

Many people need electricity, or motorised transport. Switching from greenhouse gas-producing fossil fuels to energy sources that don't harm the environment is a better way to create power.

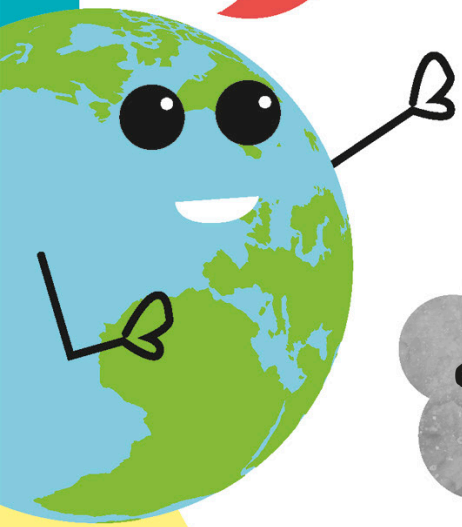
Globally, more than **25** per cent of electricity comes from renewable sources.

Wind turbines

Many countries are aiming to cut CO_2 emissions by 45 per cent by 2030.

2 Reducing demand

Using less energy means that we burn fewer fossil fuels. Actions include installing better insulation to keep homes warm instead of using more heating, turning off lights, and using electric cars rather than petrol-driven ones.

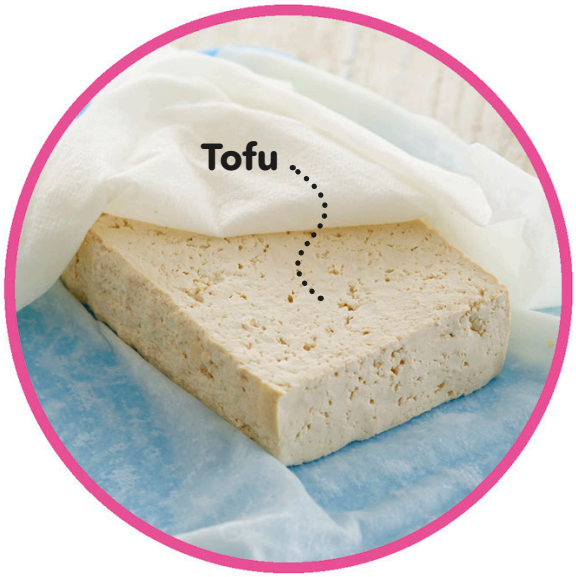


3 New ideas

Some people are coming up with new ideas to help stop the effects of global warming. One plan is to take some CO_2 out of the air with new trees, planted in huge forests. A more unusual idea is to cover glaciers with reflective blankets to stop them melting, which causes sea levels to rise.

4 Preventing deforestation

Lots of trees are chopped down so that cows can graze in open fields, which means less CO_2 is taken out of the air. Instead of raising cows for meat, we can grow plants for food. Plants such as soybeans, which make tofu, need less space and take CO_2 out of the air.



5 Reusing, recycling

Lots of energy is used to make or produce materials, to make the materials into items, and to transport the finished items to shops for sale. By reusing, we save energy. Recycling an object uses less energy than making something from scratch.

In 2015, many national leaders agreed to limit global warming to 1.5°C (2.7°F) above pre-19th century temperatures.

Planetary weather

Just like Earth, every planet has its own type of weather. However, most of this weather is entirely unsuitable for humans! Here are some of the extreme weather examples in our own Solar System.

The Sun's energy heats the circling planets.

The Sun

Mercury

Hot solar winds from the nearby Sun reach the surface of Mercury. This planet has very high temperatures during the day. However, there is no atmosphere to trap the heat, so at night temperatures can plummet to

-180°C (-290°F).

Venus

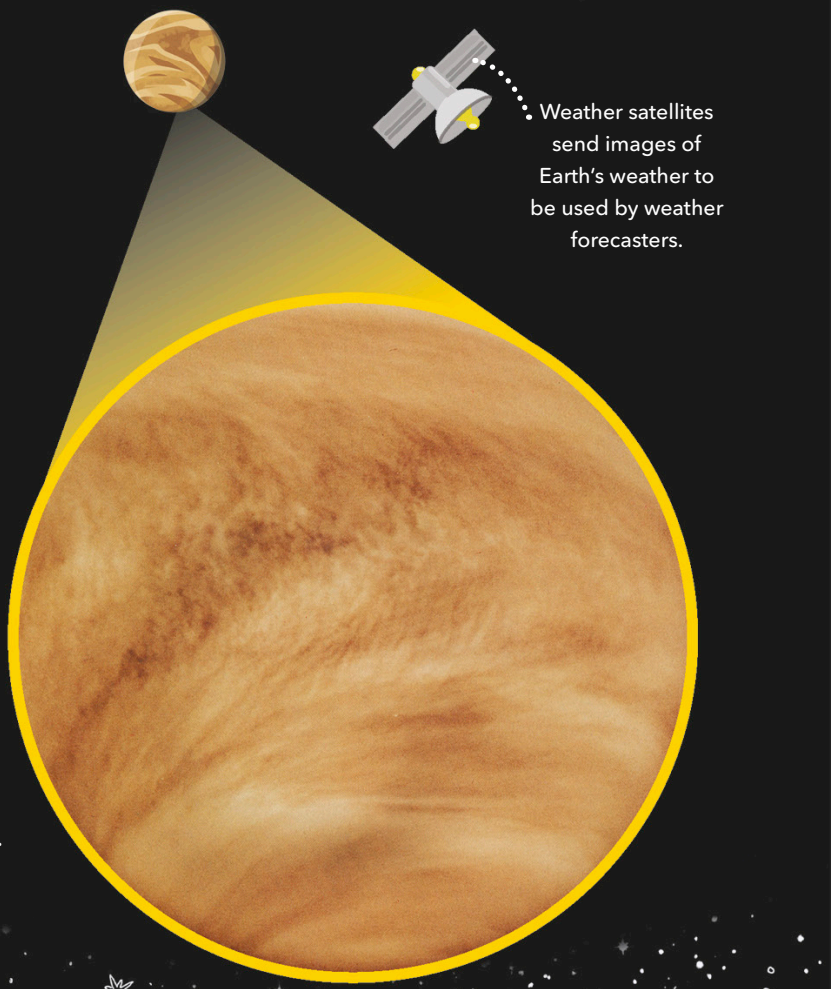
A thick atmosphere of carbon dioxide creates very hot surface temperatures. It can reach

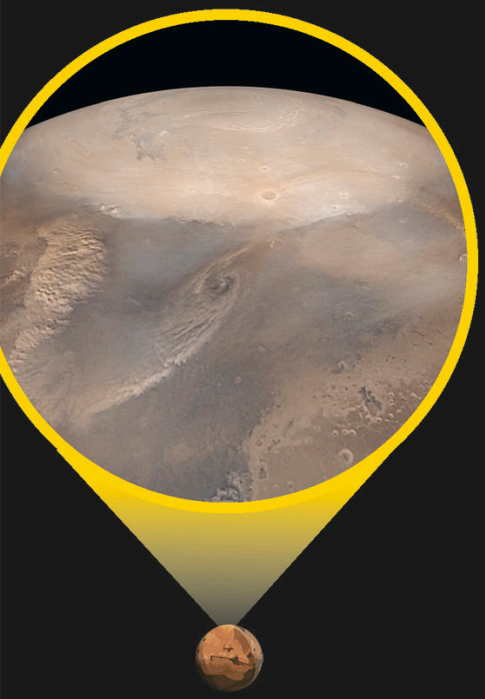
465°C (900°F).

Earth

You should know about the weather on Earth if you've got this far in the book!

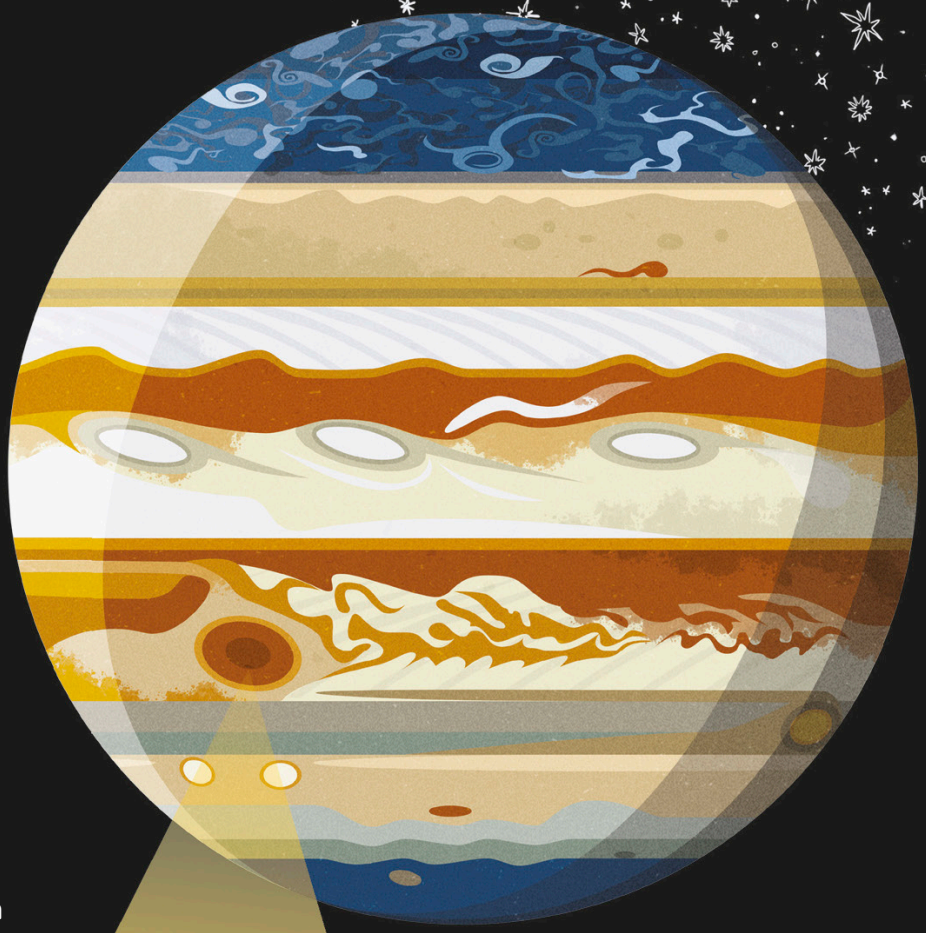
Weather satellites send images of Earth's weather to be used by weather forecasters.

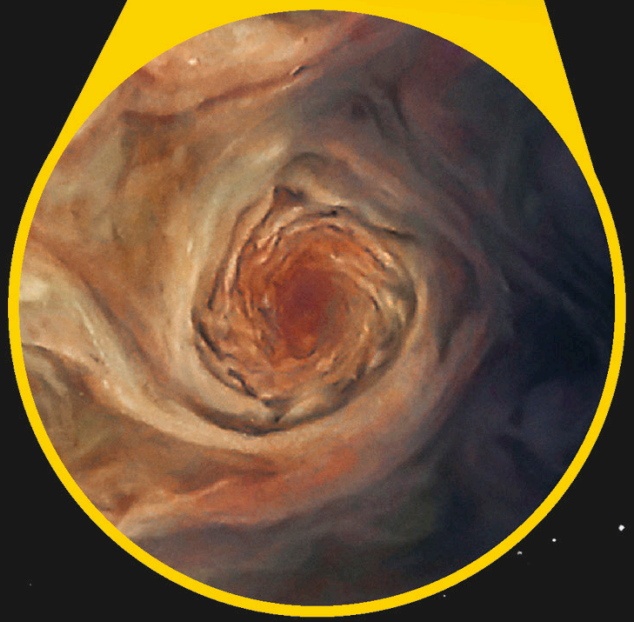




Mars

Huge dust storms rage across the surface of Mars, big enough to be seen by astronomers on Earth. The surface of Mars is much colder than our planet's, with deep, frozen poles. The seasons are longer, too.





Jupiter

The largest planet in our solar system has an incredibly stormy surface. The storms can get so big that they are visible from space!

The windy planet

Neptune is extremely windy, with violent storms swirling around the surface. Winds blow around four times faster than the winds in the strongest hurricanes on Earth! Neptune is also extremely cold because it is far away from the Sun.

Glossary

atmosphere
Layer of gases around the Earth

climate
Normal weather in any region, or large area

cloud
Huge collection of water droplets and ice crystals in the air

condensation
When water vapour turns into liquid water

current
Flow of air or water

deforestation
When forests are chopped down for wood, or to clear land for farming

energy
Something that makes things happen, such as movement or heat

Equator
Imaginary line running around the widest part of the Earth

evaporation
When liquid water turns into water vapour

forecast
Predict what the weather will be like, using information from weather-monitoring devices

fossil fuel
Gas, liquid, or solid formed naturally over many years, which is burned to make electricity or to power vehicles

gas
Matter with no fixed shape, such as air

global warming
When global temperatures increase over a long period of time

greenhouse effect
When gases trap heat in the atmosphere and warm the Earth

humidity
How much water vapour is in the air

ice
Solid water

ice crystal
Tiny piece of ice

ice sheet
Large amount of ice that covers a huge area of land

particle
Very small part of something, such as a gas

pole
Furthest north or south point of the Earth

pollution
Something with a negative effect on the environment, such as gases that increase the greenhouse effect

precipitation
Wet matter that falls from clouds, such as rain, hail, or snow

pressure
Measurement of the weight of the air

radar

Beam that detects objects, such as water droplets, by bouncing off them

recycle

Turn a waste object into something new

renewable energy

Energy from sources that won't run out, such as the Sun or wind, and which often don't produce greenhouse gases

satellite

Object made by humans that circles the Earth

season

Period of weather during the year, related to whether an area is tilted towards the Sun

solar

Related to the Sun

temperature

How hot or cold it is, usually measured in degrees (°) on a Celsius (C) or Fahrenheit (F) scale

torrential rain

Extremely heavy rain

tropical

Related to regions near the Equator

water vapour

Gas version of water

wind

Movement of air

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